Big Creek Research and Extension Team

University of Arkansas System Division of Agriculture

Quarterly Report – October 1 to December 31, 2014

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 fourth Quarterly Report of 2014 for the Big Creek Research and Extension Team that details the following progress made from October 1 through December 31, 2014.

1. Continued to collect routine baseflow water samples from Big Creek above and below the C&H Farm, along with water from the spring, culvert, surface runoff sites on Fields 1, 5a, and 12, interceptor trench below the slurry holding ponds, and house well for chemical analysis.
2. As recommended by the External Review Panel, the electrical resistivity imaging (ERI) analysis of Fields 5a and 12 was completed by Dr. Hallihan, School of Geology, Oklahoma State University in late December, 2014.
3. Installed sampling site at the mouth of Dry Creek where it enters Big Creek as suggested by the External Review Panel. Before the site became operational, it was vandalized and will be replaced in the near future.
4. Measured bacteria concentrations in Big Creek were high both above (20,140 and 173,290 MPN/100 mL as E.coli and total coliform, respectively) and below the C&H Farm (1,203 and 20,120 MPN/100 mL as E.coli and total coliform, respectively) during storm flow grab sampling on 10/13/2014, as well as trench flow below the holding ponds. However, no consistent or prolonged trends in nutrients or bacteria concentrations were evident at or among any of the monitoring locations. In fact, based on all the data collected since we started monitoring in September 2013, geometric mean bacterial levels tend to be greater under storm than base flow conditions.

	Base flow		Storm flow	
	E. coli	Total coliform	E. coli	Total coliform
	- - - - - - - - - - - - - - - - - - MPN/100 mL - - - - - - - - - - - - - - - - -			
Upstream	55	1,631	502	6,248
Downstream	52	2,633	334	6,458

A longer period of monitoring is needed for a more reliable assessment of farm impact on Big Creek water quality.

5. As inputs for the adaptive and potential alternative manure management options, determination of the contribution of barn wash-water to manure slurry volume was continued. A topographic elevation survey of the holding ponds and surrounding areas was performed to determine the as-built volumes and precipitation catchment area of each pond. A set of chemical manure treatment trials were performed with the resulting manure samples submitted for analysis.

Big Creek Research Team

Faculty

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

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

Rick Cartwright, Ph.D., Professor – Associate Director of Extension for Agriculture and Natural Resources

Mark Cochran, Ph.D., – Vice President, University of Arkansas System Division of Agriculture.

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

Tim Kresse, M.Sc., Water Quality Specialist, U.S. Geological Survey, natural geochemical evolution of groundwater and separating these processes from anthropogenic sources of contamination

Nathan McKinney, Ph.D., – Assistant Director, Agriculture Experiment Station

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

Thad Scott, Ph.D., Assistant Professor - Water quality, transport of contaminants to and within water bodies

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 excellent Program Technicians based in Little Rock and Fayetteville.

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Land Use Analysis for the Big Creek Watershed

Land use of the watershed drainage area was determined for several segments of the Big Creek Watershed (Tables 1 and 2). 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 1), Big Creek upstream of the C&H (Figure 2), downstream of the C&H Farm to the Buffalo River (Figure 3), the monitored land area encompassing fields permitted to receive manure slurry (Figure 4), and Dry Creek Watershed (Figure 5).

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 (5%) and more forest (92%) (Table 2).

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

	Upstream of C&H (Figure 2)		Downstream of C&H (Figure 3)		Monitored watershed (Figure 4)		Dry Creek watershed (Figure 5)	
Land use/Land cover	**Area (acres)**	**% of total area**	**Area (acres)**	**% of total area**	**Area (acres)**	**% of total area**	**Area (acres)**	**% of total area**
Grassland/Pasture	1,389	8.0	5,431	17.0	1,561	17.8	231	5.1
Forest								
Deciduous forest	15,110	86.5	24,297	75.9	6,570	75.1	4,036	89.0
Evergreen forest	514	2.9	1,094	3.4	250	2.9	145	3.2
Mixed forest	4	0.0	54	0.2	11	0.1	2	0.03
Shrubland	5	0.0	2	0.0	- - [2]	- -	- -	- -
Woody wetlands	0.4	0.0	0.7	0.00	0.7	0.0	- -	- -
Urban								
Developed/Open space	435	2.5	1,038	3.2	327	3.7	119	2.6
Developed/Low intensity	13.	0.1	77	0.2	23	0.3	0.7	0.01
Developed/Medium intensity	0.2	0.0	2	0.0	4	0.1	- -	- -
Developed/High intensity	- -	- -	- -	- -	1	0.1	- -	- -
Open water	- -	- -	0.9	0.0	- -	- -	- -	- -
TOTAL	**17,471**		**31,997**		**8,750**		**4,534**	

[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.

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

Land use/Land cover	Upstream of C&H		Downstream of C&H		Monitored watershed		Dry Creek watershed	
	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area	Area (acres)	% of total area
Pasture	1389	7.95	5431	16.97	1561	17.84	231	5.10
Forest	15628	89.45	25446	79.52	6830	78.09	4182	92.25
Urban	448	2.57	1118	3.49	355	4.06	120	2.64
Other	5	0.03	4	0.01	1	0.01	231	5.10

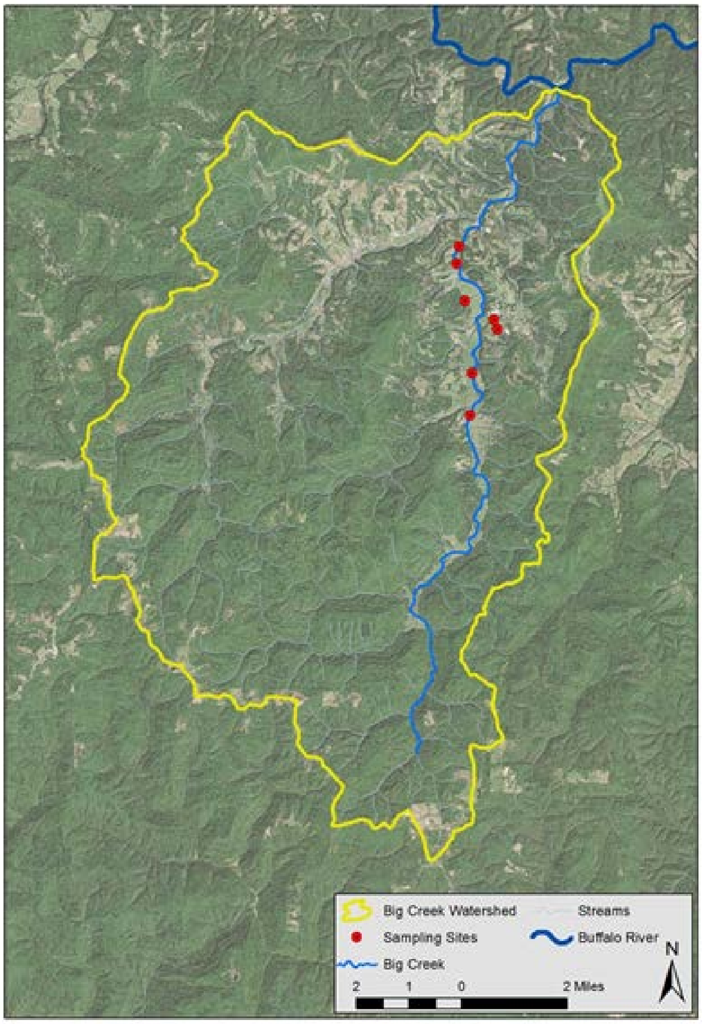

Figure 1. Big Creek Watershed with sampling sites.

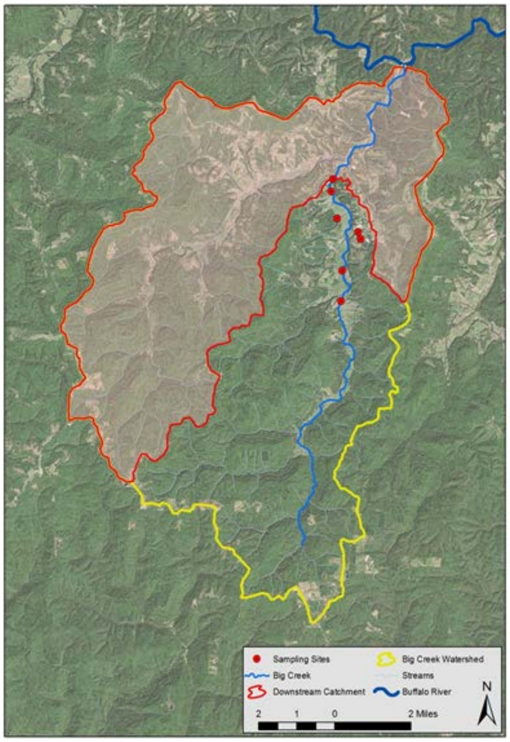

Figure 2. Delineation of the watershed downstream of the C&H to the Buffalo River.

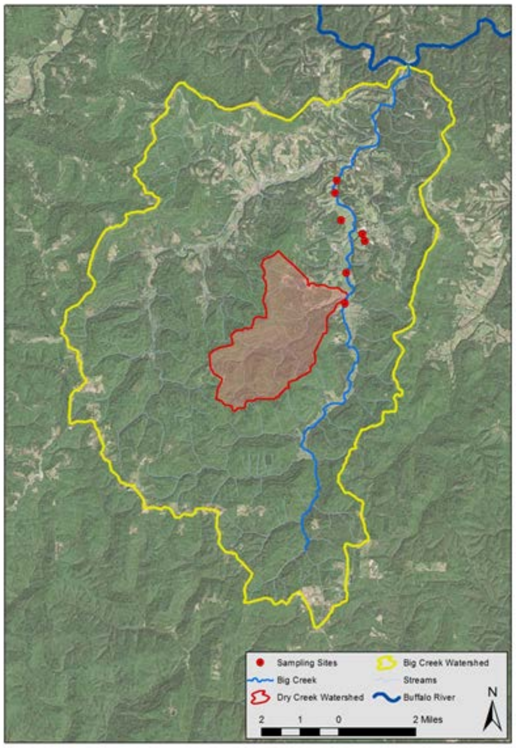

Figure 3. Dry Creek watershed.

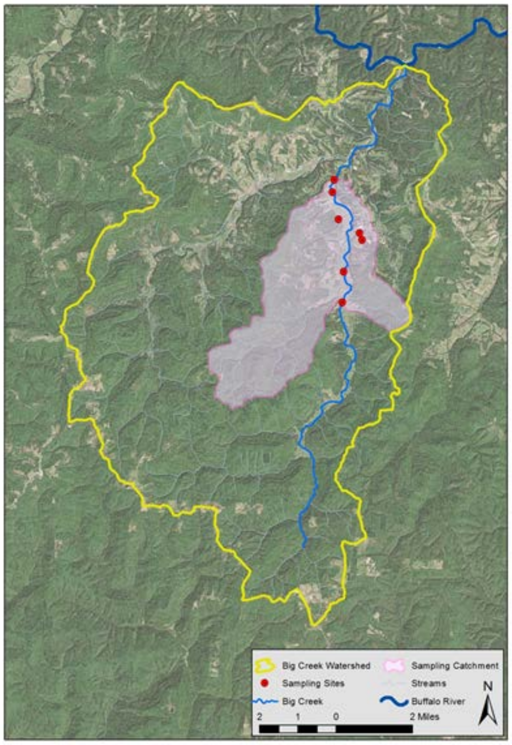

Figure 4. Delineation of the monitored watershed between upstream and downstream of the C&H Farm.

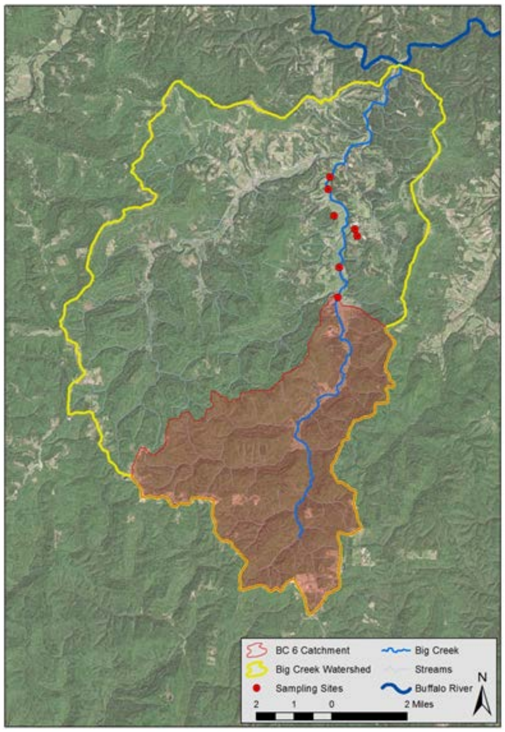

Figure 5. Watershed delineation for the upstream C&H sampling site.

Water Sampling and Analyses

Sampling Locations

Water quality monitoring sites are shown in Figure 6 and are;

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

Site 2. Edge-of-field monitoring on Field 5a.

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. Manure holding pond trench. The site was visited weekly and trench water sampled when flowing. The trenches flow periodically and flow measurement equipment will be installed during the first quarter of 2015.

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 were 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 Dissolved Phosphorus (EPA 365.2), Total Phosphorus (APHA 4500-P), Ammonia (EPA 351.2), Nitrate (EPA 300.0), Total Nitrogen (APHA 4500-N), Total Suspended Solids (EPA 160.2), E. coli (APHA 9223, B) and Total Coliforms (APHA 9223, B). 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. The minimum detection limits (MDLs) for each chemical and biological constituent measured are listed in Table 3.
8. Chemical and biological analyses of samples collected in the 4th Quarter of 2014 are presented in Tables 4, 5, and 6.

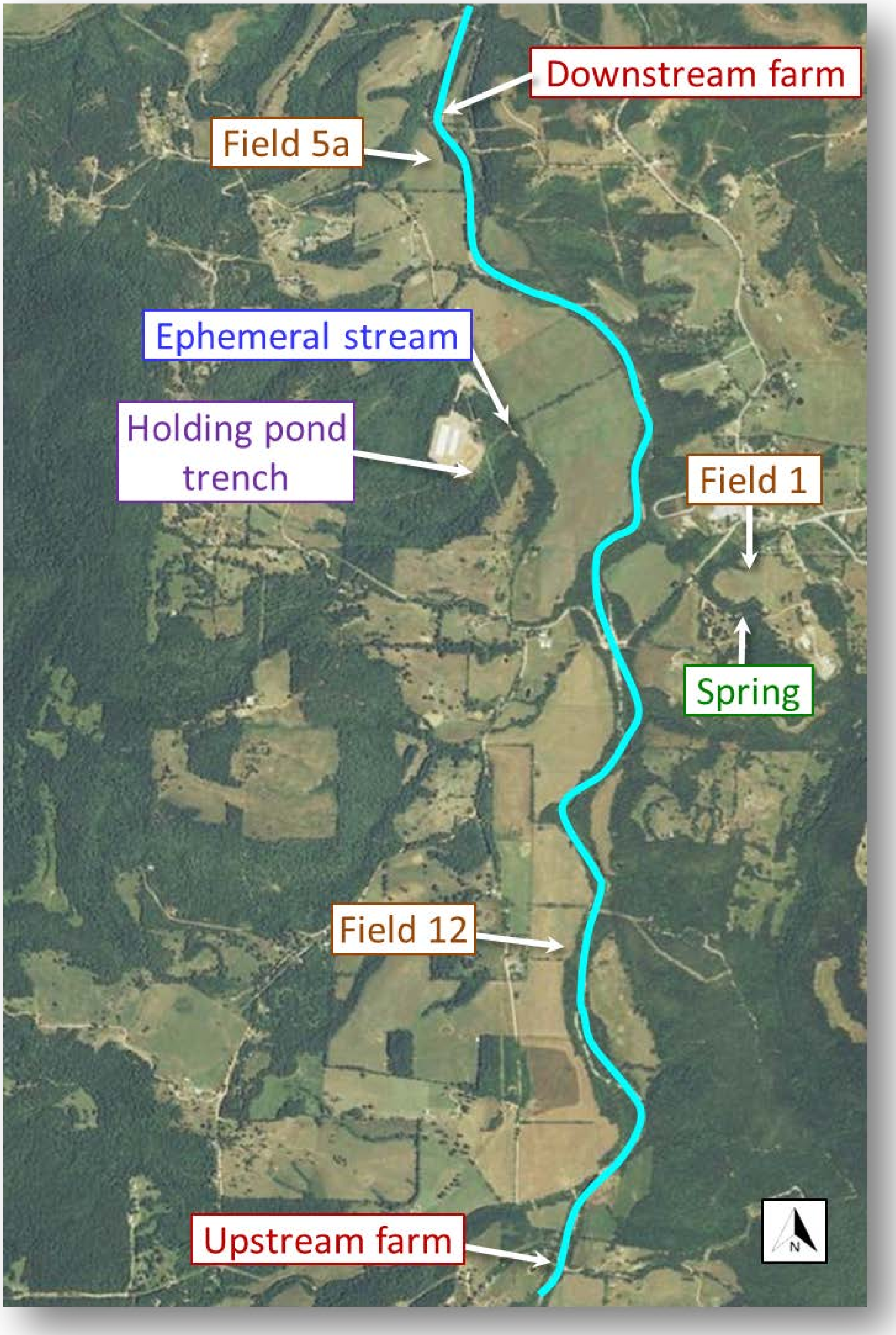

Figure 6. Location of water quality sampling sites on Big Creek and the C&H Farm.

Table 3. Minimum detection limits (MDLs) for each chemical and biological constituent measured.

Constituent	Minimum detection limit
Dissolved P, mg L^{-1}	0.002
Total P, mg L^{-1}	0.012
Ammonium-N, mg L^{-1}	0.03
Nitrate-N, mg L^{-1}	0.004
Total N, mg L^{-1}	0.006
Total suspended solids, mg L^{-1}	6.58
Dissolved organic carbon, mg L^{-1}	0.18
E. coli, MPN 100 mL^{-1}	1
Total coliform, MPN 100 mL^{-1}	1

USGS Stations

Big Creek Continuous Flow

We are collaborating with USGS, Big Creek at the downstream site of prior water sample collection, which was instrumented with continuous flow gaging equipment and a nitrate sensor, which provides real-time flow, water temperature, water nitrate and precipitation data. These data are available on line at the USGS website below. Flow and nitrate for from the USGS downstream site for the last quarter is given in Figures 7 and 8.

USGS 07055790 Big Creek near Mt. Judea, AR

http://nwis.waterdata.usgs.gov/ar/nwis/uv/?site_no=07055790&agency_cd=USGS

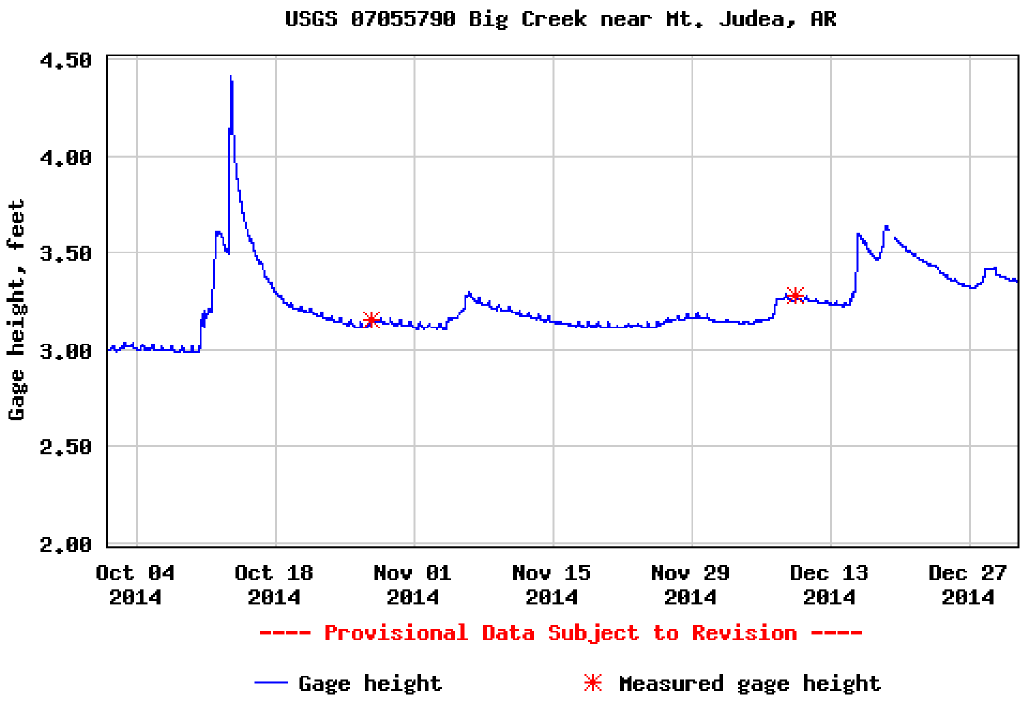

Figure 7. Big Creek flow at the monitoring site downstream of the C&H Farm during the 4th quarter of 2014.

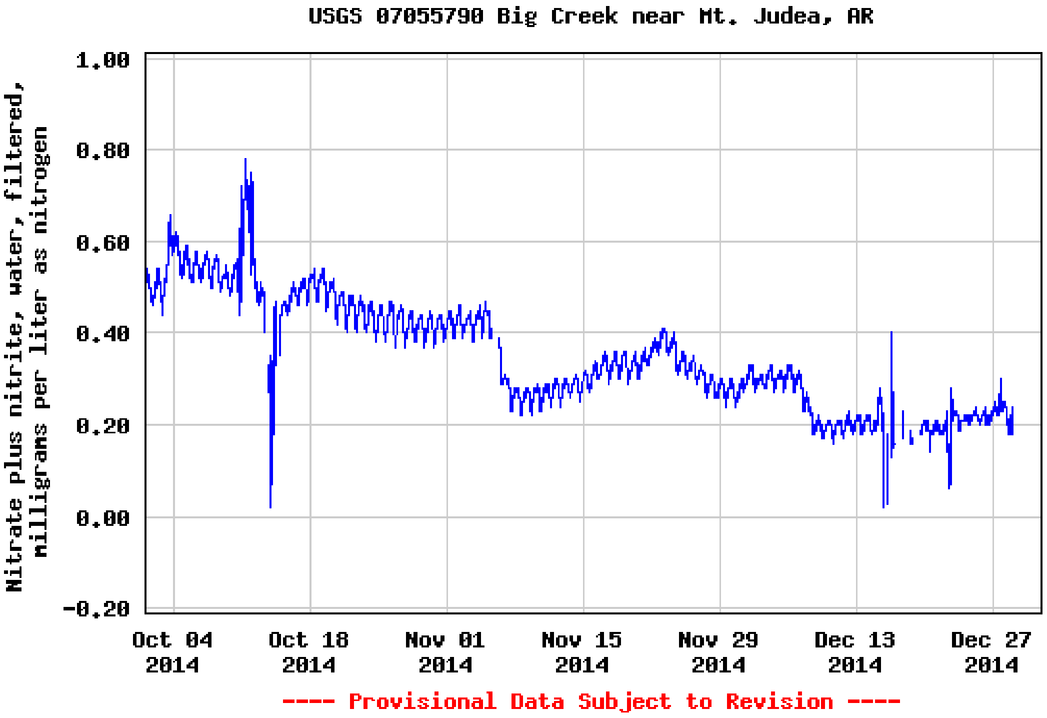

Figure 8. Nitrate concentration in Big Creek at the monitoring site downstream of the C&H Farm during the 4th quarter of 2014.

Table 4. Water quality analyses at each sample site. Coliform units are Most Probable Number (MPN) per 100 mL of water for the 4th Quarter of 2014.

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 - -	
8/12/2014	**8/12/2014**	**Base flow**									
10:09	13:23	Spring	0.009	0.032	0.03	0.217	0.26	7.0	0.56	40.4	2419
10:52	13:23	Upstream farm	0.012	0.026	<0.03	0.108	0.13	1.7	0.30	98.8	1986
9:54	13:23	Downstream farm	0.012	0.036	0.04	0.232	0.23	8.3	0.40	125.0	9870
10:37	13:23	House well	0.009	0.020	0.20	0.418	0.62	0.5	0.35	<1	<1
8/20/2014	**8/20/2014**	**Base flow**									
10:28	14:05	Spring	0.010	0.036	<0.03	0.285	0.45	7.5	1.09	307.6	40830
11:23	14:05	Upstream farm	0.014	0.040	<0.03	0.214	0.32	8.3	0.52	88.4	3000
10:14	14:05	Downstream farm	0.011	0.032	0.01	0.319	0.37	3.4	0.44	69.7	7380
10:53	14:05	House well	0.010	0.020	0.15	0.412	0.61	0.3	0.28	<1	<1
8/22/2014	**8/25/2014**	**Base flow**									
14:06	9:25	Trench, South	0.007	0.008	<0.03	0.523	0.69	5.7	1.79	N.D.	N.D.
8/26/2014	**8/26/2014**	**Base flow**									

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
11:38	14:23	Spring	0.007	0.078	0.05	0.256	0.42	38.6	0.35	51.2	4650
12:08	14:23	Upstream farm	0.005	0.064	0.09	0.075	0.42	6.5	1.21	3.1	4370
11:14	14:23	Downstream farm	0.013	0.018	0.01	0.398	0.46	1.4	0.22	19.7	5120
11:56	14:23	House well	0.008	0.022	0.26	0.378	0.66	0.4	0.18	<1	<1
9/3/2014	**9/3/2014**	**Storm flow**									
10:24	13:28	Spring	0.008	0.022	<0.03	0.227	0.37	10.9	0.61	1870.0	21430
11:15	13:28	Upstream farm	0.010	0.030	0.04	0.303	0.52	5.3	0.67	270	8570
9:39	13:28	Downstream farm	0.015	0.018	<0.03	0.500	0.60	3.5	0.09	65.7	4040
10:40	13:28	House well	0.011	0.008	0.17	0.475	0.68	2.9	0.02	56.3	59.1
11:36	13:28	Trench 1	0.004	0.003	0.04	0.937	1.22	3.7	0.68	N.D.	N.D.
9/11/2014	**9/11/2014**	**Storm flow**									
11:48	15:20	Spring	0.004	0.012	<0.03	0.564	0.65	1.3	0.16	35.4	7440
12:56	15:20	Upstream farm	0.001	0.040	0.06	0.198	0.53	6.2	2.28	2419.2	81640
11:31	15:20	Downstream farm	0.010	0.024	0.04	0.476	0.52	1.5	0.24	980.4	15970
12:43	15:20	House well	0.006	0.010	0.00	0.495	0.52	0.3	<0.18	<1.0	<1

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
12:35	15:20	Trench 1	0.001	0.018	0.03	1.580	1.86	1.0	0.54	1.0	57940
12:29	15:20	Trench 2	<0.002	0.010	0.03	2.033	2.31	3.2	0.70	81.3	27550
9/18/2014	**9/18/2014**	**Storm flow**									
10:42	13:42	Spring	0.007	0.200	0.17	0.170	0.6	54.7	3.12	12590.0	81640
11:25	13:42	Upstream farm	0.006	0.024	0.02	0.555	0.66	3.7	0.69	365.4	11720
9:54	13:42	Downstream farm	0.013	0.028	0.02	0.523	0.61	2.1	0.33	579.4	11530
11:06	13:42	House well	0.009	0.014	0.01	0.494	0.52	<6.6	<0.18	35.0	6940
9/23/2014	**9/23/2014**	**Base flow**									
1:05	15:28	Spring	0.001	0.024	<0.03	0.253	0.37	6.7	0.93	201.4	2750
12:45	15:28	Upstream farm	0.003	0.022	0.02	0.152	0.27	3.5	0.82	9.7	2419
10:59	15:28	Downstream farm	0.010	0.026	0.02	0.442	0.53	2.7	0.50	47.1	2620
12:27	15:28	House well	0.006	0.018	<0.03	0.494	0.53	0.5	0.33	8.5	866
9/30/2014	**9/30/2014**	**Base flow**									
10:56	14:36	Spring	0.002	0.138	<0.03	0.256	0.63	81.8	0.53	135.4	13960
12:20	14:36	Upstream farm	0.002	0.032	0.01	0.172	0.46	6.1	1.09	5.2	4320

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
9:57	14:36	Downstream farm	0.011	0.032	0.01	0.444	0.57	1.9	0.45	85.7	2560
11:10	14:36	House well	0.007	0.012	<0.03	0.501	0.56	0.3	0.17	2.0	43.5
10/8/2014	**10/8/2014**	**Base flow**									
10:24	14:46	Spring	0.001	0.050	<0.03	0.218	0.41	22.1	0.64	88.4	7330
12:11	14:46	Upstream farm	0.003	0.052	0.04	0.125	0.53	8.7	1.61	24.6	4260
9:31	14:46	Downstream farm	0.009	0.028	0.03	0.474	0.57	2.1	0.45	56.3	5630
11:01	14:46	House well	0.006	0.018	0.03	0.486	0.54	1.1	0.19	1.0	69.1
10/13/2014	**10/13/2014**	**Storm flow ISCO**									
10:07	13:45	Upstream farm	<0.005	0.072	0.03	0.124	0.46	20.8	3.36	N.D.	N.D.
9:21	13:45	Downstream farm	0.110	0.450	0.23	0.257	1.03	171.2	4.77	N.D.	N.D.
11:33	13:45	Culvert	0.004	0.068	0.08	0.996	1.37	11.2	3.28	N.D.	N.D.
9:55	13:45	Field 1	0.529	0.746	0.98	0.698	2.89	65.7	9.46	N.D.	N.D.
10:48	13:45	Field 5a	0.707	0.926	0.36	0.068	0.91	38.1	5.34	N.D.	N.D.
10/13/2014	**10/13/2014**	**Storm flow grab**									
9:38	13:45	Spring	0.005	0.126	0.12	0.083	0.62	46.5	6.55	19350	198630

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
10:11	13:45	Upstream farm	0.069	0.200	0.10	0.147	0.55	28.4	4.59	20140	173290
9:31	13:45	Downstream farm	0.015	0.058	0.05	0.379	0.51	7.0	2.30	1203.3	20120
11:00	13:45	House well	0.005	0.016	<0.03	0.496	0.56	0.3	0.23	28.1	2750
11:15	13:45	Trench 1	<0.002	0.024	<0.03	1.251	1.46	71.4	0.83	15650.0	61310
11:10	13:45	Trench 2	0.001	0.116	0.33	1.714	2.73	11.1	4.14	920.8	241920
10/22/2014	**10/22/2014**	**Base flow**									
10:24	15:23	Spring	0.006	0.058	<0.03	0.402	0.59	26.1	0.87	1046.2	5210
11:56	15:23	Upstream farm	0.010	0.026	<0.03	0.123	0.15	0.6	0.61	67.6	2430
10:09	15:23	Downstream farm	0.011	0.028	<0.03	0.380	0.47	2.0	0.59	200.0	4350
11:11	15:23	House well	0.007	0.016	<0.03	0.497	0.5	0.2	0.24	5.2	81
10/30/2014	**10/30/2014**	**Base flow**									
11:30	15:16	Spring	<0.002	0.048	0.04	0.360	0.58	23.5	0.61	110.0	3950
9:53	15:16	Upstream farm	0.005	0.016	<0.03	0.114	0.12	0.5	0.44	31.8	2419
11:47	15:16	Downstream farm	0.006	0.016	<0.03	0.368	0.42	1.8	0.42	20.1	2330
11/5/2014	**11/5/2014**	**Storm flow**									

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
9:29	15:26	Spring	0.013	0.088	0.11	0.145	0.50	13.4	3.91	579.4	11530
11:31	15:26	Upstream farm	0.018	0.032	<0.03	0.103	0.18	0.7	1.22	214.3	5040
9:10	15:26	Downstream farm	0.014	0.023	<0.03	0.353	0.48	2.1	0.78	153.9	4190
10:25	15:26	Trench 1	0.004	0.012	0.02	1.54	1.67	0.9	0.37	N.D.	N.D.
10:14	15:26	Trench 2	0.004	0.032	0.03	3.375	3.65	33.1	0.87	N.D.	N.D.
11/12/2014	**11/12/2014**	**Base flow**									
10:22	15:30	Spring	0.011	0.024	<0.03	0.095	0.16	<6.6	0.50	65	3310
10:38	15:30	Upstream farm	0.012	0.036	<0.03	0.065	0.10	0.5	0.40	57.3	3130
9:27	15:30	Downstream farm	0.012	0.026	<0.03	0.217	0.31	1.2	0.39	14.6	4350
11/24/2014	**11/24/2014**	**Storm flow**									
9:39	12:55	Spring	0.007	0.014	<0.03	0.271	0.48	4.1	4.71	40.2	2419
10:34	12:55	Upstream farm	0.013	0.013	<0.03	0.097	0.11	0.7	2.15	72.7	2419
9:23	12:55	Downstream farm	0.014	0.016	<0.03	0.297	0.38	1.5	2.11	14.8	2419
9:53	12:55	House well	0.010	0.010	<0.03	0.452	0.57	1.9	2.81	<1.0	5.2
12/4/2014	**12/4/2014**	**Base flow**									

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
10:49	15:25	Spring	0.007	0.024	<0.03	0.317	0.50	2.3	5.57	5.2	1120
11:10	15:25	Upstream farm	0.011	0.022	<0.03	0.103	0.13	0.7	2.94	45.7	1850
10:35	15:25	Downstream farm	0.013	0.024	<0.03	0.264	0.33	1.5	2.98	7.4	2990
12/9/2014	**12/9/2014**	**Storm flow**									
10:00	14:00	Spring	0.008	0.024	<0.03	0.295	0.48	2.3	4.26	18.9	1203
10:33	14:00	Upstream farm	0.011	0.024	0.01	0.057	0.09	0.5	1.60	36.4	1986
9:38	14:00	Downstream farm	0.013	0.022	<0.03	0.179	0.23	1.1	1.42	35	2650

N.D. is No Data.

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

Table 5. Water quality analyses at the spring and in Big Creek upstream and downstream of the C&H Farm boundary of permitted land application fields for the 4th Quarter of 2014.

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 - - -	
8/12/2014 Base flow									
Spring	0.009	0.032	0.03	0.217	0.26	7.0	0.56	40.4	2419
Upstream	0.012	0.026	<0.03	0.108	0.13	1.7	0.30	98.8	1986
Downstream	0.012	0.036	0.04	0.232	0.23	8.3	0.40	125.0	9870
8/20/2014 Base flow									
Spring	0.010	0.036	<0.03	0.285	0.45	7.5	1.09	307.6	40830
Upstream	0.014	0.040	<0.03	0.214	0.32	8.3	0.52	88.4	3000
Downstream	0.011	0.032	0.01	0.319	0.37	3.4	0.44	69.7	7380
8/26/2014 Base flow									
Spring	0.007	0.078	0.05	0.256	0.42	38.6	0.35	51.2	4650
Upstream	0.005	0.064	0.09	0.075	0.42	6.5	1.21	3.1	4370
Downstream	0.013	0.018	0.01	0.398	0.46	1.4	0.22	19.7	5120
9/3/2014 Storm flow									

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Spring	0.008	0.022	<0.03	0.227	0.37	10.9	0.61	1870.0	21430
Upstream	0.010	0.030	0.04	0.303	0.52	5.3	0.67	270.0	8570
Downstream	0.015	0.018	<0.03	0.500	0.6	3.5	0.09	65.7	4040
9/11/2014	**Storm flow**								
Spring	0.004	0.012	<0.03	0.564	0.65	1.3	0.16	35.4	7440
Upstream	0.001	0.040	0.06	0.198	0.53	6.2	2.28	2419.2	81640
Downstream	0.010	0.024	0.04	0.476	0.52	1.5	0.24	980.4	15970
9/18/2014	**Storm flow**								
Spring	0.007	0.200	0.17	0.170	0.60	54.7	3.12	12590.0	81640
Upstream	0.006	0.024	0.02	0.555	0.66	3.7	0.69	365.4	11720
Downstream	0.013	0.028	0.02	0.523	0.61	2.1	0.33	579.4	11530
9/23/2014	**Base flow**								
Spring	0.001	0.024	<0.03	0.253	0.37	6.7	0.93	201.4	2750
Upstream	0.003	0.022	0.02	0.152	0.27	3.5	0.82	9.7	2419
Downstream	0.010	0.026	0.02	0.442	0.53	2.7	0.50	47.1	2620

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
9/30/2014	**Base flow**								
Spring	0.002	0.138	<0.03	0.256	0.63	81.8	0.53	135.4	13960
Upstream	0.002	0.032	0.01	0.172	0.46	6.1	1.09	5.2	4320
Downstream	0.011	0.032	0.01	0.444	0.57	1.9	0.45	85.7	2560
10/8/2014	**Base flow**								
Spring	0.001	0.050	<0.03	0.218	0.41	22.1	0.64	88.4	7330
Upstream	0.003	0.052	0.04	0.125	0.53	8.7	1.61	24.6	4260
Downstream	0.009	0.028	0.03	0.474	0.57	2.1	0.45	56.3	5630
10/13/2014	**Storm flow ISCO**								
Upstream	<0.005	0.072	0.03	0.124	0.46	20.8	3.36	N.D.	N.D.
Downstream	0.110	0.450	0.23	0.257	1.03	171.2	4.77	N.D.	N.D.
10/13/2014	**Storm flow grab**								
Spring	0.005	0.126	0.12	0.083	0.62	46.5	6.55	19350.0	198630
Upstream	0.069	0.200	0.10	0.147	0.55	28.4	4.59	20140.0	173290
Downstream	0.015	0.058	0.05	0.379	0.51	7.0	2.30	1203.3	20120

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
10/22/2014	**Base flow**								
Spring	0.006	0.058	<0.03	0.402	0.59	26.1	0.87	1046.2	5210
Upstream	0.010	0.026	<0.03	0.123	0.15	0.6	0.61	67.6	2430
Downstream	0.011	0.028	<0.03	0.380	0.47	2.0	0.59	200.0	4350
10/30/2014	**Base flow**								
Spring	<0.002	0.048	0.04	0.360	0.58	23.5	0.61	110.0	3950
Upstream	0.005	0.016	<0.03	0.114	0.12	0.5	0.44	31.8	2419
Downstream	0.006	0.016	<0.03	0.368	0.42	1.8	0.42	20.1	2330
11/5/2014	**Storm flow**								
Spring	0.013	0.088	0.11	0.145	0.50	13.4	3.91	579.4	11530
Upstream	0.018	0.032	<0.03	0.103	0.18	0.7	1.22	214.3	5040
Downstream	0.014	0.023	<0.03	0.353	0.48	2.1	0.78	153.9	4190
11/12/2014	**Base flow**								
Spring	0.011	0.024	<0.03	0.095	0.16	<6.6	0.50	65	3310
Upstream	0.012	0.036	<0.03	0.065	0.10	0.5	0.40	57.3	3130

Sample location	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
Downstream	0.012	0.026	<0.03	0.217	0.31	1.2	0.39	14.6	4350
11/24/2014	**Storm flow**								
Spring	0.007	0.014	<0.03	0.271	0.48	4.1	4.71	40.2	2419
Upstream	0.013	0.013	<0.03	0.097	0.11	0.7	2.15	72.7	2419
Downstream	0.014	0.016	<0.03	0.297	0.38	1.5	2.11	14.8	2419
12/4/2014	**Base flow**								
Spring	0.007	0.024	<0.03	0.317	0.50	2.3	5.57	5.2	1120
Upstream	0.011	0.022	<0.03	0.103	0.13	0.7	2.94	45.7	1850
Downstream	0.013	0.024	<0.03	0.264	0.33	1.5	2.98	7.4	2990
12/9/2014	**Storm flow**								
Spring	0.008	0.024	<0.03	0.295	0.48	2.3	4.26	18.9	1203
Upstream	0.011	0.024	0.01	0.057	0.09	0.5	1.60	36.4	1986
Downstream	0.013	0.022	<0.03	0.179	0.23	1.1	1.42	35	2650

N.D. is No Data.

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

Table 6. Water quality analyses at the culvert draining the subwatershed containing the production houses and manure holding ponds, the well adjacent to the ponds, and surface runoff from Field 1 for the 4th Quarter of 2014.

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 - - -	
Culvert									
10/13/2014	0.004	0.068	0.08	0.996	1.37	11.2	3.28	N.D.	N.D.
House well									
8/12/2014	0.009	0.020	0.20	0.418	0.62	0.5	0.35	<1	<1
8/20/2014	0.010	0.020	0.15	0.412	0.61	0.3	0.28	<1	<1
8/26/2014	0.008	0.022	0.26	0.378	0.66	0.4	0.18	<1	<1
9/3/2014	0.011	0.008	0.17	0.475	0.68	2.9	0.02	56.3	59.1
9/11/2014	0.006	0.010	<0.03	0.495	0.52	0.3	<0.18	<1.0	<1
9/18/2014	0.009	0.014	0.01	0.494	0.52	<6.6	<0.18	35.0	6,940
9/23/2014	0.006	0.018	<0.03	0.494	0.53	0.5	0.33	8.5	866
9/30/2014	0.007	0.012	<0.03	0.501	0.56	0.3	0.17	2.0	43.5
10/8/2014	0.006	0.018	0.03	0.486	0.54	1.1	0.19	1.0	69.1
10/13/2014	0.005	0.016	<0.03	0.496	0.56	0.3	0.23	28.1	2,750

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
10/22/2014	0.007	0.016	<0.03	0.497	0.5	0.2	0.24	5.2	81.3
11/24/2014	0.010	0.010	<0.03	0.452	0.57	1.9	2.81	<1.0	5.2
8/22/2014	0.007	0.008	<0.03	0.523	0.69	5.7	1.79	N.D.	N.D.
Interceptor Trench 1 (South)									
9/3/2014	0.004	0.003	0.04	0.937	1.22	3.7	0.68	N.D.	N.D.
9/11/2014	0.001	0.018	0.03	1.580	1.86	1.0	0.54	1.0	57,940
10/13/2014	<0.002	0.024	<0.03	1.251	1.46	71.4	0.83	15,650.0	61,310
11/5/2014	0.004	0.012	0.02	1.54	1.67	0.9	0.37	N.D.	N.D.
11/12/2014	0.004	0.012	0.02	1.54	1.67	0.9	0.37	N.D.	N.D.
Interceptor Trench 2 (North)									
9/11/2014	<0.002	0.010	0.03	2.033	2.31	3.2	0.70	81.3	27,550
10/13/2014	0.001	0.116	0.33	1.714	2.73	11.1	4.14	920.8	241,920
11/5/2014	0.004	0.032	0.03	3.375	3.65	33.1	0.87	N.D.	N.D.
11/12/2014	0.004	0.032	0.03	3.375	3.65	33.1	0.87	N.D.	N.D.
Field 1 Surface runoff									

Date sample collected	Dissolved P	Total P	Ammonia-N	Nitrate-N	Total N	Total suspended solids	Dissolved Organic C	E. coli	Total coliform
10/13/2014	0.529	0.746	0.98	0.698	2.89	65.7	9.46	N.D.	N.D.
Field 5a Surface runoff									
10/13/2014	0.707	0.926	0.36	0.068	0.91	38.1	5.34	N.D.	N.D.

N.D. is No Data.

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

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.

Statistical Analysis

Statistical analysis of the limited amount of data collected so far in Big Creek above and below the C&H Farm (one year with 52 samples at each location over a range of flow conditions). Based on the water chemistry before December 30, 2013, it appears that;

- Total nitrogen concentrations were low (<0.6 mg/L on average) relative to more developed watersheds across the Ozark and Boston Mountains,
- Nitrate- nitrogen concentrations increased slightly (0.1 mg/L) downstream from the application fields, whereas total nitrogen concentrations did not change relative to upstream of the C&H Farm operation,
- The slight increase in nitrate is probably reflective of the land use continuum and historic management, and
- Based on the analysis of samples collected to date, other water-quality parameters did not change significantly ($p<0.05$ level) at our monitoring sites upstream to downstream of the C&H Farm operation.

Based on water chemistry before and after December 30, 2014, it appears that;

- Nitrogen concentrations decreased upstream and downstream reflecting seasonal variability, which is typical in streams draining the Ozark and Boston Mountains,
- Phosphorus concentrations and coliform numbers did not change over time upstream or downstream of the C&H Farm operation, but continued monitoring is needed to understand how land application of the manure might possibly influence water chemistry.

Coliform Numbers in Big Creek Above and Below C&H Farm:

- Based on the analysis of Big Creek water samples collected before December 30, 2013, there was no significant ($p<0.05$) change in E. coli and total coliform numbers at our monitoring sites upstream to downstream of the C&H Farm operation.
- Based on the analysis of Big Creek water samples collected before and after December 30, 2014, E. coli and total coliform numbers have not changed over time, but continued monitoring is needed to understand how land application of the manure might possibly influence water chemistry.
- E. coli concentrations were high in trench flow samples on October 13th, 2014 and total coliform concentration on the same date and September 11th, 2014, although other parameters such as dissolved P and nitrate were not elevated on October 13 relative to dates before or after. The site was visited weekly and trench water sampled when flowing. While these appear to be isolated high levels at the moment and may result from construction contamination flushing, we will continue to sample the trench water as well as monitoring pond influx and level. However, the elevated numbers have prompted the determination of other water quality parameters such as chloride, electrical conductivity and total dissolved solids to help interpret these numbers. Also, to eliminate the possibility of external contamination of the trench water samples, we are

installing equipment to protect trench flow at the point at which samples are taken from external contamination.

To put the measured bacteria concentrations into a State water quality standard perspective, the criteria set by Arkansas Department of Environmental Quality (ADEQ) are given. Water quality standards for *E. coli* are established by the state in ADEQ Regulation 2 (see Table 7). The *E. coli* numbers must remain below a threshold in a specified number of total samples collected. The exact upper limit that is allowed depends on the designation of the waterbody and time of year (primary or secondary contact season). *Primary contact recreation* is a designation given to a waterbody where full body contact occurs and occurs from May 1 through September 30.

ADEQ also designates any stream with a watershed (e.g. drainage basin in the landscape) exceeding 10 square miles and those with smaller watersheds on individual cases (i.e. after site verification) for primary contact recreation. *Secondary contact recreation* designates waterbodies where activities such as boating, fishing, and wading take place and occurs from October 1 through April 30.

Table 7. Upper limits for Escherichia coli counts defined in Regulation 2 of the Arkansas Department of Environmental Quality (ADEQ) as specified by contact season and waterbody designation for both single samples and geometric mean.

Contact season	**Water designation**	**Limit of *E. coli* (MPN/100mL)**	
		Single sample[1]	Geometric mean[2]
Primary (May 1-Sept. 30)	Extraordinary Resource Water Ecologically Sensitive Waterbody Natural & Scenic Waterways, Lakes, & Reservoirs	298	126
	All other water	410	NA[3]
Secondary (Oct. 1-April 30)	Extraordinary Resource Water Ecologically Sensitive Waterbody Natural & Scenic Waterways, Lakes, & Reservoirs	1490	630
	All other water	2050	NA

[1] No more than 25% of samples from no less than 8 samples per contact season may exceed the limit.

[2] Geometric mean is calculated from at least 5 samples collected within 30 days at evenly spaced time intervals during that 30-day period.

[3] Not applicable.

Electrical Resistivity Imaging Analysis

Electrical resistivity imaging (ERI) analysis provides a good method to understand the distribution of fluids and rock properties in the subsurface environment especially in the presence of fractures or karst features. The method allows an electrical image to be created with a resolution of half the distance between electrodes, which typically provides a meter-scale dataset that can be utilized to evaluate heterogeneity and fluid distribution. Improvements in sensitivity generated by the Halihan/Fenstemaker method allow greater differentiation of these signatures. In a field setting, this will result in a two-dimensional mapping of subsurface electrical properties for each dataset, which will be used to interpret groundwater movement in a complex mantled karst with applied manures.

As part of cooperative research, Oklahoma State University (OSU) designed and conducted ERI experiments and will integrate ERI data with well and other site data to provide an understanding of the subsurface distribution of flowpaths at a background and manure study site. Dr. Todd Halihan and his graduate research assistant (OSU) travelled to the sites to conduct the imaging and data collection. University of Arkansas (UA) provided 2-3 field assistants to aid in collecting data and clearing brush. Aestus, LLC was utilized to provide 3-D visualization of the field data utilizing RockWorks™. Data analysis and reporting will be performed in conjunction with research team members at UA and Aestus, LLC.

The work was conducted in late December, 2014 and data quality is anticipated to be high due to the geologic setting lacking metallic infrastructure. The resistivity structure of the site will be evaluated with OSU working with UA and Aestus to ensure proper integration of the ERI acquisition location and scale with the UA well and soil sampling protocols. More detailed information on the ERI methods and analyses is given in Appendix 1.

The results of the work will be reported to UA, and published in appropriate journal locations. The work is intended to be applied to understanding best management practices for conducting land application of agricultural waste in karstic settings. Data acquired during the ERI analysis of Fields 5a and 12 will be processed and analyzed by OSU researchers during the first quarter of 2015 and results will be made available in the next Quarterly Report, due April 15, 2015.

Manure Management Inputs Determination Efforts

The volume of manure produced by a livestock is largely determined by the average animal population characteristics, freshwater additions (if any), spilled drinking water (if any), and pen wash down water. In addition, any precipitation directly into manure storages or via surface runoff will increase manure volume.

Wash-water volume determination

Discussions with C&H management revealed that the farm used “wet/dry” feeders so that any animal drinking water spillage would fall into the feed troughs and consumed with the feed. As a result, there will be effectively no spilled drinking water adding to manure slurry volume. Estimates for pen wash down water were provided in the form of the number of pressure washers, the flow rates in gallons per minute, and the average time spent washing each day. As a more direct determination of pen wash water additions to the manure was desired, two standard water meters were purchased and installed to measure all the water used by two pressure washers used in the barns (Figure 9).

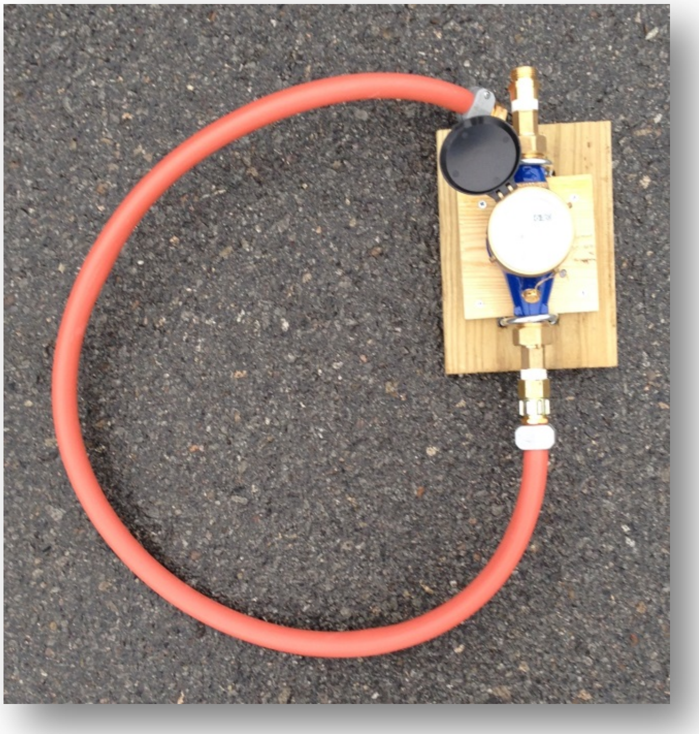

Figure 9. Standard water meter with hose adapters and mounting base installed to measure water use during pressure washing to clean animal pens.

Periodically, pictures of the meters were submitted providing readings and the date of the readings to document cumulative and daily wash-water volumes added to the manure slurry volume. From March 20, 2014 to September 9, 2014 a total of 161,722 gallons of water was used to wash the pens with the water then draining into the manure pits. The average daily water use over these 174 days was 929 gallons/day. (Table 8 and Figures 10 and 11).

Table 8. Pen wash-water meter readings and water volumes in gallons.

Date	Days	Meter 1			Meter 2			Total	
		Reading	Cumulative	Daily average	Reading	Cumulative	Daily average	Cumulative	Daily average
		---------------------------- Gallons ----------------------------------							
3/20/2014		126.5			80.2				
9/10/2014	174	96,610	96,483	554	65,319	65,239	375	161,722	929

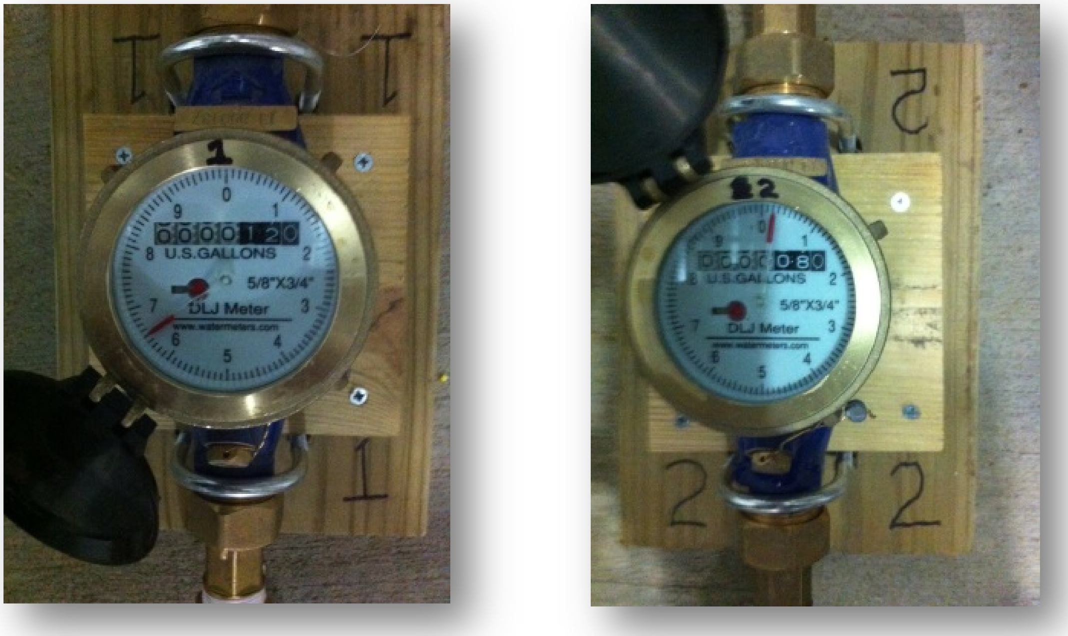

Figure 10. Two water meters purchased and installed on March 20th, 2014 to measure pen wash down water additions to manure volume. Initial meters readings were 126.6 and 80.2 gallons for meter 1 and 2.

Figure 11. Two water meters purchased and installed on March 20th, 2014 to measure pen wash down water additions to manure volume. Meters readings were 96,609.6 and 65,319.3 gallons for meter 1 and 2 on September 10th, 2014.

Topographic Elevation Survey of Holding Ponds

To quantify potential precipitation additions to the manure volume, a topographic elevation survey of the catchments for the holding ponds was conducted utilizing total station survey equipment. This survey measured the elevation at various locations around the holding ponds, as well as points on the interior slopes and bottoms of the ponds. The survey was followed by a second survey utilizing a traditional transit and "Philidelphia rod," which measured elevation at various points on the outside the ponds to document drainage patterns away from the ponds. In addition, visual inspections and photographs were made to provide additional inputs. All this information was utilized to build a Graphical Information System (GIS) surface model that provides both precipitation capture area of the holding ponds and storage volumes of holding ponds (Table 9 and Figure 12). This pond information and historical rainfall information are being used to estimate potential precipitation additions to manure slurry volume.

Table 9. Summary information for the topographic survey surface modeling area and volume.

Pond	Area	Total volume [1]	Available storage [2]
	ft^2	gallon	gallon
Pond 1	16,999 [3]	743,011	616,395
Pond 2	34,618 [3]	1,977,675	1,723,009
Sum of Pond 1 & 2	51,617	2,720,686	2,339,403
Drainage area into ponds [4]	59,457	Not applicable	Not applicable

[1] Area of the top of the pond's 1 ft deep freeboard zone.

[2] Area in which water would drain into the ponds during a precipitation event.

[3] Total volume from the bottom of the pond to the top of the freeboard.

[4] Available storage is the total volume minus a 6 inch bottom layer assumed as unpumpable and the top 1 ft freeboard layer.

Figure 12. Yellow outer boundary denotes the drainage area (59,457 ft^2) into the holding ponds. The red inner boundary denotes area of the top of the free board for holding Pond 1 (16,999 ft^2) and Pond 2 (34,618 ft^2).

Chemical Manure Treatment Trials

A guiding concept of the chemical treatment trials is the goal of sustainable preferential separation of the manure into a P-rich portion for transport to more distant locations for utilization, and phosphorus-poor portion for closer utilization. In addition, due to the fact that P is a finite resource, it is desirable to retain P in manure for beneficial use, where P is needed for optimal crop production. For this reason, we investigated the effectiveness of calcium (Ca) binding with manure P enhanced by natural settling of manure solids. In principal, after addition of Ca to manure various Ca phosphate compounds are formed, which settle out with manure solids. Depending on the chemical and physical properties of the settled solids, the necessary mechanical and structural components of a manure separation system could be designed to meet the transportation needs and hopefully economic constraints of the farm enterprise. More detail of the manure treatment trials is given in Appendix 2.

Future Plan of Work

1. Analyze and interpret the ERI results for Fields 5a and 12 to determine the potential for subsurface areas of preferential flow pathways.
2. Continue to collect surface runoff, spring, and stream samples after each rainfall event from the autosamplers and manually collect baseflow samples weekly from the house well (when it is turn back on after the risk of freezing), spring, and streams. All analyses will be analyzed for N, P, sediment, and bacteria (E. coli and total coliform from baseflow grab samples).
3. Collect water samples from the piezometers installed in Fields 5a and 12.
4. Re-install equipment to monitor flow, nutrients and sediment in Dry Creek entering Big Creek.
5. Repeat grid-soil sampling of Fields 1, 5a, and 12.
6. Continue to periodically determine plant uptake by collecting plant and hay samples for tissue analysis and determine yield (dry-matter mass for a pre-determined area).
7. Install equipment to measure the liquid flow from the production houses and determine pond height. In combination with weather data and interceptor trench monitoring, this will provide another indication of whether the holding ponds are leaking from the bottom
8. Precipitation inputs, average daily wash-down water, and manure holding pond volumes will be used to estimate annual manure and nutrient production values. These values, coupled with chemical treatment trial results, will form the basis for investigating manure management alternatives.

Appendix 1 – Electrical Resistivity Imaging Analysis Methods

Electrical Resistivity Imaging of Mantled Karst in the Buffalo River Basin, Arkansas

Todd Halihan, Professor, Boone Pickens School of Geology, Oklahoma State University

Electrical resistivity imaging (ERI) provides a good method to understand the distribution of fluids and rock properties in the subsurface environment especially in the presence of fractures or karst features (Bolyard, 2007, Smith et al., 2008, Gary et al., 2009, Halihan et al., 2009). The method allows an electrical image to be created with a resolution of half the distance between electrodes, which typically provides a meter-scale dataset that can be utilized to evaluate heterogeneity and fluid distribution. Improvements in sensitivity generated by the Halihan/Fenstemaker method (OSU, 2004) allow greater differentiation of these signatures (Miller et al, in press). In a field setting, this will result in a two-dimensional mapping of subsurface electrical properties for each dataset.

For these experiments, the electrical imaging will be conducted on a one time basis to evaluate rock properties, but can also be repeated on a pre- and post-infiltration basis to generate images of changes in the electrical properties (Albano et al., 2010, Halihan et al., 2011). These transient datasets will allow an understanding of changes in fluid electrical properties as the infiltrating fluid and associated reactions will be the only subsurface change. The datasets will be used to interpret groundwater movement in a complex mantled karst with applied agricultural waste.

As part of cooperative research, Oklahoma State University (OSU) will design and conduct ERI imaging experiments and integrate ERI data with well data and other site data to provide an understanding of the subsurface distribution of flowpaths at a background and waste application study sites. Dr. Todd Halihan and his graduate research assistant (OSU) will travel to the sites to assist in experimental setup of the imaging and collecting initial data. University of Arkansas (UA) will provide 2-3 field assistants to aid in collecting data and clearing brush as needed. Aestus, LLC will be utilized to provide 3-D visualization of the field data utilizing RockWorks™. Data analysis and reporting will be performed in conjunction with research team members at UA and Aestus, LLC. The work is anticipated to begin 1 October 2014 and conclude 30 September 2015.

Potential hurdles for the research are field logistics and constraints due to site access and stream access. For this site, data quality is anticipated to be high due to the geologic setting lacking metallic infrastructure. The resistivity structure of the site will be evaluated with OSU working with UA and Aestus to ensure proper integration of the ERI acquisition location and scale with the UA well and soil sampling protocols.

The results of the work will be reported to UA, and published in appropriate journal locations. The work is intended to be applied to understanding best management practices for conducting land application of agricultural waste in karstic settings.

1.0 Scope of Work

ERI data will be collected at two sites near Mount Judea, Arkansas (Figure 1). A total of 18 ERI lines are planned to be acquired and visualized in 3-D. Current planning involves acquiring data along 10 transect lines at the northern site (MJN; Site 1) (Figures 1 and 2), and 8 transect lines at the southern site (MJS; Site 2) (Figures 1 and 3). A dozen lines will be acquired at a ~1.5 meter resolution (3 meter electrode spacing), providing datasets that are ~165 meters long horizontally with a depth of imaging of approximately 33 meters. An additional six higher resolution transect lines are planned at a ~0.5 meter resolution (1 meter electrode spacing) to provide higher resolution imaging of pathways observed during the acquisition of the coarser data for each site. It is anticipated that two field acquisition efforts will be required to ensure proper data acquisition and integration. The locations of lines may need to be shifted as field conditions dictate, relative to land access or thick vegetation.

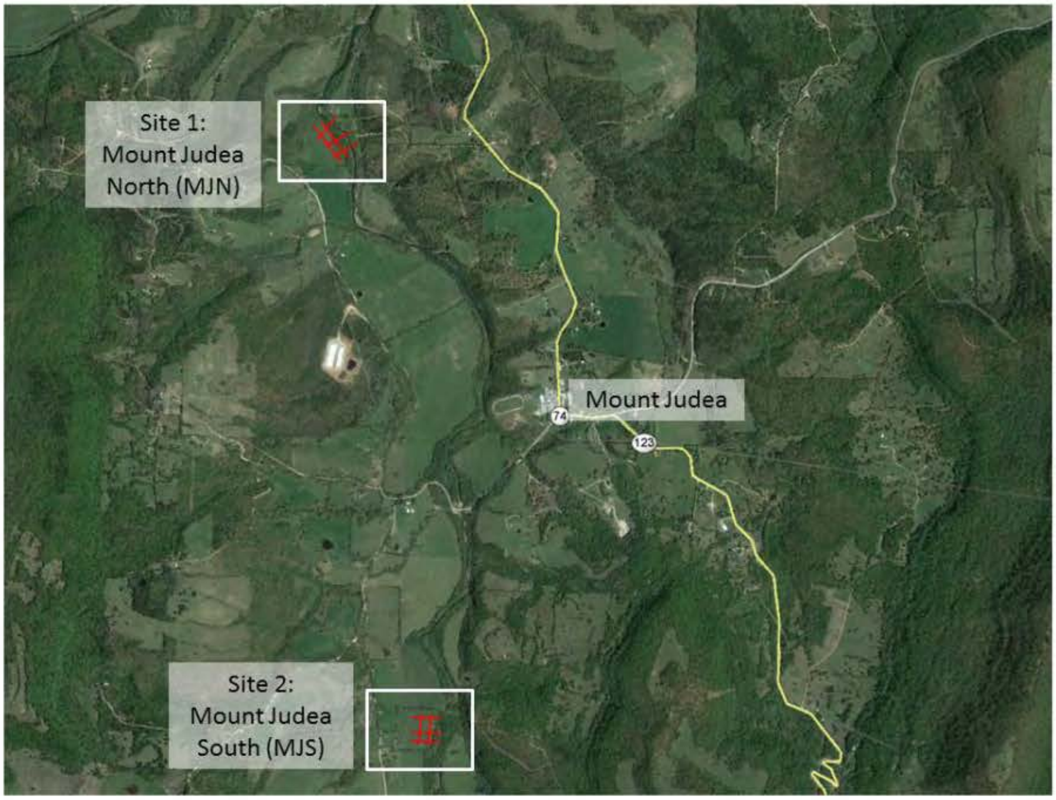

Figure 1. Location of sites for ERI imaging near Mount Judea, Arkansas.

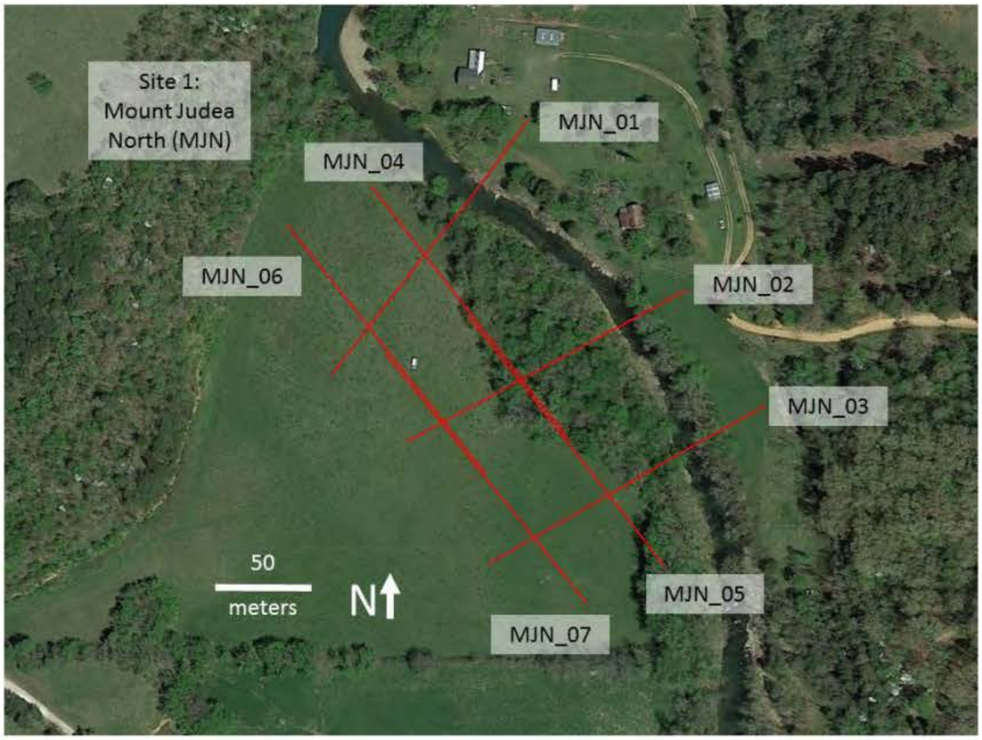

Figure 1. Location of ERI lines at northern (downgradient) site MJN. Seven 165 meter long lines illustrated. 3 additional high resolution lines (placement not shown) will be acquired after evaluating initial data.

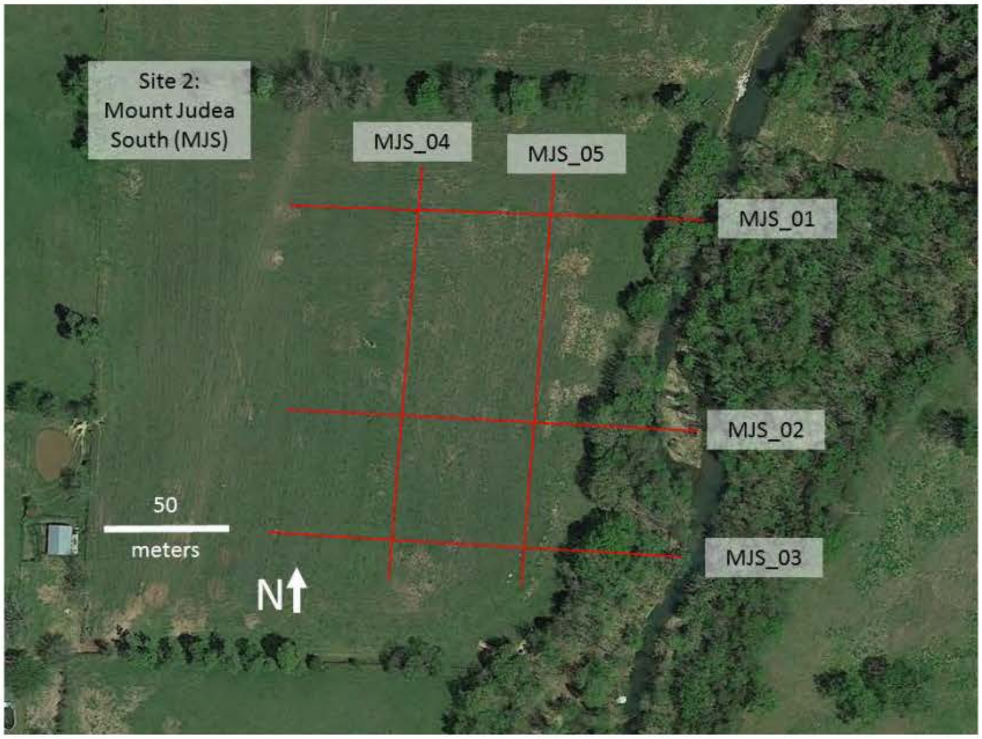

Figure 2. Location of ERI lines at southern (upgradient) site MJS. Five 165 meter long lines illustrated. 3 additional high resolution lines (placement not shown) will be acquired after evaluating initial data.

1.0.1 Assumptions for OSU

The work plan assumes the following for OSU:

1. OSU will utilize their own resistivity instrumentation for acquisition of ERI data.
2. OSU will utilize their own GPS instrumentation for acquisition of 3-D survey data.
3. ERI data can be obtained on the sites as they are largely natural settings.
4. GPS can be obtained on the sites as they are largely cleared fields.
5. OSU will work with Aestus, LLC to visualize the data. Note that Dr. Halihan has a managed conflict of interest between OSU and Aestus, LLC.

1.0.2 Assumptions for UA

The work plan assumes the following for UA:

1. UA will provide 2-3 field assistants on site to assist with acquiring ERI and survey data.
2. UA will work with land owners to obtain legal access for the OSU field team and answer questions regarding the field work.
3. UA will provide well data to OSU to include in the visualization model of the site data.

3.0 References

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Appendix 2 – Summary of Chemical Manure Treatment Trials

Two sources of Ca for the trials were Ca hydroxide ($Ca(OH)_2$) and agricultural lime ($CaCO_3$). The Ca hydroxide was added to manure slurry in either a liquid slurry form (30% by weight) or as a dry powder. The agricultural lime was added in the dry fine granular form, which is routinely land applied to adjust soil pH. Liquid slurry Ca hydroxide was applied to manure slurry on a volumetric (mL/mL) basis at 0, ½, 1, and 2 times the target treatment rate. The target treatment rate was determined by mixing various amounts of Ca hydroxide slurry to 500 mL of manure in clear containers. After allowing time for settling, a visual inspection was used to set the target treatment rate as 5%, (50 mL/1000 mL) (Figure 13). The dry Ca addition rates were at equivalent elemental Ca rates as the liquid Ca treatments (Table 10).

Figure 13. Calcium hydroxide slurry treatment test results. Bottle labels represent 0, 1, 2, 3, 4, 6, 8, and 10% Ca treatments. Based on both the clarity of the top liquid and settled solids a target rate of 5% was select for the chemical amendment trial.

Table 10. Chemical treatment rates based a 5% (mL/mL) target mixture rate of Ca hydroxide to manure slurry and 17 liters of manure slurry.

Chemical and form	Treatment rate			
	O x Target rate	½ x Target rate	1 x Target rate	2 x Target rate
Ca Hydroxide, 30% (gm/gm) slurry	0 mL	425 mL	850 mL	1700 mL
Ca Hydroxide, dry powder	O gm	154 gm	307 gm	614 gm
Ca Carbonate, dry fine granular	O gm	207 gm	415 gm	830 gm

As any chemical treatment system would likely treat the manure as it discharges from the barns and before it enters holding Pond 1, a manure collection and mixing system was designed for this chemical trial (Figure 14). On the day of the trial (September 4th, 2014), a pump was used to capture a portion of the manure discharged from the barns into holding Pond 1 as one of the manure pits was being drained. The captured manure was pumped into a 360 gallon tank via two mixing nozzles to ensure uniform mixing of the manure slurry in the tank.

Once this tank was filled, a discharge valve was opened to drain a portion of the collected manure into holding Pond 1. By adjusting the discharge valve and pump throttle, the manure flow rate into and out of the tank were balanced resulting in the tank manure volume remaining fixed (Figure 14). This balanced-flow process continued until the manure pit in the barn had been drained and a composite sample of all the manure slurry from the drained pit was collected. After manure was collected was completed, valves were closed so that the pump continually mixed manure slurry in the tank (Figure 14).

Figure 14. Manure collection and mixing system. Discharge valve for pulling manure for treatment is above the front corner of the tank base.

Manure was drained from the tank into 5 gallon buckets in 17 liter volumes as needed for the chemical treatments. Before any settling could occur, the mixture was poured into a second bucket lined with a filter bag and a subsample collected for analysis. This process was repeated until three replicates of each chemical/rate combination in Table 10 had been prepared.

At this time the each filter bag was lifted from its bucket and allowed to drain for 3 minutes. Then samples of the concentrated manure slurry in the filter bag and the leachate from the bucket were sampled for analysis.

After the manure from the filter bags were sampled, tripods were used to suspend them above their bucket (Figure 15). The combination of buckets and tripods were placed under a cover, which allowed for full air movement while protecting them from rainfall and damage from animals. After 5 days (September 9th, 2014), the filter bags were dry enough that they were placed on tables to reduce the potential for wind damage and rewetting of the bags (Figure 16). On September 15th, 2014, a total of 10 days after treatment, the manure slurry mixture in the filter bags and leachate in the 5 gallon buckets was mixed and sampled for analysis.

Figure 15. Filter bags containing separated manure slurry suspended above their respective buckets of leachate.

Figure 16. Leachate buckets and filter bags after the separated solids were dry enough for placement on tables for additional drying.

A total of 93 samples were collected the day the manure slurry was treated, with an additional 62 samples collected after treatment for 10 days. The chemical analyses have been completed and the results have begun to be analyzed for the next phase of the manure treatment trial. Initial information from the first trial and descriptive codes of the manure slurry samples are given in Tables 11 and 12.

Table 11. Descriptive code format for chemically treated manure samples.

Treatment		
	Ca source/Rate/Material sampled/ Day sample collected/Replicate	
Example	LS 1 M 1 A	
Interpretation	Lime Slurry, 1 x target rate, mixed, day of treatment, first replicate	
Ca Source		
LS	Lime Surry on 30% wt. basis	
HL	Hydrated lime dry powder	
AL	Ag Lime Dry granules	
CS	Control sample	
Rate		
0	Control no additive	
0.5	1/2 x Target Rate	
1	1 x Target Rate	
2	2 x Target Rate	
Material Sampled		
M	Mixed after Ca addition prior to filtering	
L	Leachate after filtration	
P	Precipitate after filtration	
Day Sample Collected		
1	Sampled day of treatment	
2	Sampled after days of storage	
Replication		**Control Sample Details**
A	1st Replicate	Control Sample collected prior to LS samples
B	2nd Replicate	Control Sample collected prior to HS samples
C	3rd Replicate	Control Sample collected prior to AL samples
D	4th Replicate	Control Sample collected after AL samples

Table 12. Analysis results summary form chemically treated manure samples.

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
	%		- mg/kg -						
1CS0LA	0.96	7.56	1476	803	BDL	325	1335	176	152
1CS0LB	0.89	7.62	1289	730	BDL	318	1358	207	141
1CS0LC	1.08	7.60	1467	737	BDL	428	1323	299	144
1CS0LD	0.94	7.61	1486	743	BDL	315	1272	246	102
1CS0L Average	**0.97**	**7.60**	**1429**	**753**		**346**	**1322**	**232**	**135**
1LS½LA	0.91	10.32	1252	570	BDL	101	1320	299	19
1LS½LB	1.06	12.70	833	497	BDL	45	1258	872	9
1LS½LC	0.92	10.09	1145	583	BDL	115	1305	356	20
1LS½L Average	**0.96**	**11.04**	**1077**	**550**		**87**	**1294**	**509**	**16**
1LS1LA	0.96	12.66	891	398	BDL	22	1222	592	9
1LS1LB	1.00	12.67	980	507	BDL	34	1201	709	9
1LS1LC	0.89	12.68	1011	474	BDL	35	1270	690	11
1LS1L Average	**0.95**	**12.67**	**961**	**460**		**30**	**1231**	**664**	**9**
1LS2LA	1.07	12.72	938	457	BDL	27	1200	942	6

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
1LS2LB	1.20	12.75	916	440	BDL	27	1217	999	5
1LS2LC	1.06	12.72	858	491	BDL	25	1207	938	6
1LS2L Average	**1.11**	**12.73**	**904**	**463**		**26**	**1208**	**959**	**6**
1HL½LA	0.93	9.09	1213	711	BDL	187	1327	422	51
1HL½LB	0.94	8.90	1246	707	BDL	220	1351	405	57
1HL½LC	0.98	8.87	1294	721	BDL	259	1344	432	58
1HL½L Average	**0.95**	**8.95**	**1251**	**713**		**222**	**1341**	**419**	**56**
1HL1LA	0.93	9.19	1290	683	BDL	185	1329	406	56
1HL1LB	0.91	9.38	1249	683	BDL	141	1320	392	41
1HL1LC	0.91	9.57	1245	689	BDL	135	1281	464	36
1HL1L Average	**0.92**	**9.38**	**1261**	**685**		**154**	**1310**	**421**	**44**
1HL2LA	0.89	12.24	1133	511	BDL	58	1294	409	17
1HL2LB	0.99	12.60	1149	529	BDL	53	1323	559	12
1HL2LC	0.99	12.55	1155	522	BDL	56	1282	503	13
1HL2L Average	**0.96**	**12.46**	**1145**	**521**		**56**	**1300**	**490**	**14**
1AL½LA	0.91	7.56	1323	693	BDL	270	1264	210	153

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
1AL½LB	0.90	7.62	1335	719	BDL	291	1310	250	92
1AL½LC	0.93	7.60	1351	766	BDL	308	1346	270	71
1AL½L Average	**0.91**	**7.59**	**1336**	**726**		**290**	**1307**	**243**	**105**
1AL1LA	1.07	7.58	1361	736	BDL	352	1316	615	84
1AL1LB	0.90	7.61	1319	776	BDL	271	1291	270	75
1AL1LC	0.97	7.58	1350	764	BDL	292	1336	351	82
1AL1L Average	**0.98**	**7.59**	**1343**	**759**		**305**	**1315**	**412**	**80**
1AL2LA	0.98	7.61	1319	759	BDL	290	1313	494	78
1AL2LB	1.19	7.62	1372	758	BDL	350	1312	920	89
1AL2LC	1.08	7.63	1334	732	BDL	312	1300	682	84
1AL2L Average	**1.08**	**7.62**	**1342**	**750**		**317**	**1308**	**699**	**84**
1CS0PA	2.50	7.45	2037	851	BDL	1090	1431	926	226
1CS0PB	2.67	7.45	1940	803	BDL	1166	1393	1086	213
1CS0PC	4.53	7.33	2709	782	BDL	2068	1368	1974	300
1CS0PD	3.86	7.28	2689	810	BDL	1763	1327	1717	258
1CS0P Average	**3.39**	**7.38**	**2344**	**812**		**1522**	**1380**	**1426**	**249**

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
1LS½PA	8.00	12.48	2358	610	0.35	2355	1430	15573	21
1LS½PB	10.10	12.49	2611	653	BDL	2787	1345	17487	22
1LS½PC	8.05	12.51	2447	612	BDL	2371	1416	14752	21
1LS½P Average	**8.71**	**12.49**	**2472**	**625**	**0.35**	**2505**	**1397**	**15937**	**21**
1LS1PA	11.54	12.72	2739	705	BDL	2138	1299	23213	11
1LS1PB	11.62	12.71	2719	683	0.35	2167	1280	23904	14
1LS1PC	13.76	12.70	3208	762	0.50	2754	1339	29446	17
1LS1P Average	**12.31**	**12.71**	**2889**	**716**	**0.43**	**2353**	**1306**	**25521**	**14**
1LS2PA	12.66	12.75	2184	653	BDL	1731	1262	34284	4
1LS2PB	11.25	12.74	1975	580	BDL	1487	1245	30856	2
1LS2PC	10.42	12.74	1972	617	BDL	1411	1251	28106	2
1LS2P Average	**11.45**	**12.74**	**2044**	**617**		**1543**	**1253**	**31082**	**3**
1HL½PA	14.43	12.67	3020	838	BDL	3098	1350	29408	16
1HL½PB	13.37	12.65	3011	777	BDL	2574	1222	24630	14
1HL½PC	10.05	12.68	2606	798	BDL	2282	1329	19686	14
1HL½P Average	**12.62**	**12.67**	**2879**	**804**		**2651**	**1300**	**24575**	**15**

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
1HL1PA	11.19	12.74	2668	741	BDL	2611	1323	23139	15
1HL1PB	15.05	12.76	2704	860	BDL	2638	1276	33244	7
1HL1PC	16.61	12.75	2726	783	0.67	2731	1245	39822	5
1HL1P Average	**14.28**	**12.75**	**2699**	**795**	**0.67**	**2660**	**1281**	**32068**	**9**
1HL2PA	20.51	12.78	2301	648	BDL	2086	1173	52339	3
1HL2PB	21.31	12.80	2343	654	BDL	1999	1158	54756	3
1HL2PC	18.94	12.80	2336	736	BDL	1884	1192	47195	3
1HL2P Average	**20.25**	**12.79**	**2327**	**679**		**1990**	**1174**	**51430**	**3**
1AL½PA	9.39	7.16	3207	855	BDL	2950	1308	15912	531
1AL½PB	7.33	7.32	2991	874	BDL	2273	1258	11874	402
1AL½PC	9.17	7.26	2972	874	BDL	2681	1266	13791	509
1AL½P Average	**8.63**	**7.25**	**3056**	**868**		**2635**	**1277**	**13859**	**481**
1AL1PA	7.25	7.34	2674	824	BDL	1922	1274	13517	370
1AL1PB	11.62	7.17	3085	874	BDL	2588	1194	26354	530
1AL1PC	8.00	7.18*	2718	847	BDL	2233	1343	15489	413
1AL1P Average	**8.95**	**7.23**	**2826**	**848**			**1270**	**18454**	**438**

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
1AL2PA	19.63	7.20	2600	787	BDL	2330	1233	36401	626
1AL2PB	14.88	7.23	3014	823	BDL	2444	1252	38626	533
1AL2PC	19.84	7.28	3284	817	BDL	2551	1160	47155	657
1AL2P Average	**18.12**	**7.24**	**2966**	**809**		**2442**	**1215**	**40727**	**605**
2CS0LA	1.11	7.97	991	483	BDL	499	1536	246	127
2CS0LB	1.21	8.00	874	420	BDL	516	1515	845	147
2CS0LC	1.09	8.11	881	406	BDL	476	1555	220	147
2CS0LD	1.09	8.06	969	462	BDL	509	1538	263	125
2CS0L Average	**1.12**	**8.04**	**929**	**443**		**500**	**1536**	**393**	**137**
2LS½LA	1.00	8.52	335	65	BDL	178	1527	755	27
2LS½LB	1.03	8.77	341	66	BDL	184	1416	739	25
2LS½LC	1.16	8.34	440	94	BDL	288	1450	1182	38
2LS½L Average	**1.06**	**8.54**	**372**	**75**		**217**	**1465**	**892**	**30**
2LS1LA	1.07	12.54	190	17	BDL	92	1541	1172	10
2LS1LB	0.95	12.55	207	43	0.45	62	1435	848	10
2LS1LC	0.93	12.46	193	35	BDL	58	1408	755	10

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
2LS1L Average	**0.98**	**12.52**	**197**	**32**	**0.45**	**71**	**1461**	**925**	**10**
2LS2LA	2.02	12.71	196	44	BDL	120	1429	3193	4
2LS2LB	1.71	12.72	161	36	BDL	67	1453	2158	4
2LS2LC	2.00	12.70	212	47	BDL	111	1367	3190	5
2LS2L Average	**1.91**	**12.71**	**190**	**42**		**99**	**1416**	**2847**	**5**
2HL½LA	0.54	8.24	420	198	BDL	128	879	277	37
2HL½LB	0.60	8.17	453	217	0.55	148	920	268	38
2HL½LC	0.65	8.04	519	215	BDL	233	1118	440	42
2HL½L Average	**0.60**	**8.15**	**464**	**210**	**0.55**	**170**	**972**	**328**	**39**
2HL1LA	1.18*	8.31	601	207	BDL	316	1524	897	45
2HL1LB	1.16	8.37	562	208	BDL	299	1546	1147	40
2HL1LC	1.26	8.30	553	196	BDL	300	1581	1198	46
2HL1L Average	**1.20**	**8.33**	**572**	**204**		**305**	**1551**	**1081**	**44**
2HL2LA	1.07	9.60	216	42	0.45	183	1292	1500	18
2HL2LB	1.30	12.21	242	21	BDL	132	1539	1063	13
2HL2LC	1.41	12.42	329	62	BDL	204	1511	1721	11

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
2HL2L Average	**1.26**	**11.41**	**262**	**42**	**0.45**	**173**	**1447**	**1428**	**14**
2AL½LA	1.18*	7.95	1002	495	BDL	491	1485	822	162
2AL½LB	1.21	8.02	933	420	BDL	500	1494	815	158
2AL½LC	0.67	7.86	644	377	BDL	280	1054	88	115
2AL½L Average	**1.02**	**7.94**	**860**	**431**		**423**	**1345**	**575**	**145**
2AL1LA	1.34	8.10	948	475	BDL	490	1595	1268	151
2AL1LB	1.34	8.01	954	447	0.36	492	1542	1332	151
2AL1LC	1.33	8.01	956	436	BDL	514	1565	1382	140
2AL1L Average	**1.34**	**8.04**	**952**	**453**	**0.36**	**499**	**1567**	**1327**	**147**
2AL2LA	1.44	8.10	931	454	BDL	431	1528	1826	147
2AL2LB	1.34	8.13	951	452	BDL	436	1510	1835	145
2AL2LC	1.30	8.09	874	444	BDL	416	1536	1688	141
2AL2L Average	**1.36**	**8.11**	**918**	**450**		**428**	**1525**	**1783**	**144**
2CS0PA	27.70	8.80	9652	1153	BDL	12692	3053	14069	1059
2CS0PB	26.73	8.86	12258	1151	BDL	14631	3542	16162	977
2CS0PC	25.00	8.08	8605	760	BDL	12413	3975	13003	1222

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
2CS0PD	30.69	8.96	12838	1266	BDL	15026	3694	15962	1246
2CS0P Average	**27.53**	**8.68**	**10838**	**1083**		**13690**	**3566**	**14799**	**1126**
2LS½PA	28.61	9.24	4051	254	BDL	9551	2491	65309	196
2LS½PB	23.83	8.31	3988	82	3.05	9929	2628	67821	227
2LS½PC	31.64	8.90	4140	172	BDL	9770	2769	65084	184
2LS½P Average	**28.03**	**8.82**	**4060**	**169**	**3.05**	**9750**	**2629**	**66071**	**203**
2LS1PA	34.58	12.60	4072	178	BDL	9053	2767	104067	35
2LS1PB	32.26	12.64	4137	157	5.39	7509	2104	88832	26
2LS1PC	30.78	12.63	3934	155	2.19	7633	2116	85937	32
2LS1P Average	**32.54**	**12.62**	**4047**	**164**	**3.79**	**8065**	**2329**	**92945**	**31**
2LS2PA	34.18*	12.70	1316	138	BDL	5520	1872	128405	20
2LS2PB	33.78	12.66	3234	146	BDL	5521	1920	125661	21
2LS2PC	33.53	12.65	2500	174	BDL	5511	1740	117627	21
2LS2P Average	**33.83**	**12.67**	**2350**	**153**		**5517**	**1844**	**123898**	**21**
2HL½PA	31.84	12.46	4857	317	2.19	10120	2856	80281	57
2HL½PB	31.75	12.62	4519	419	2.31	10691	2898	69858	51

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
2HL½PC	34.16	12.61	4148	420	4.53	11973	4206	80854	23
2HL½P Average	**32.58**	**12.56**	**4508**	**385**	**3.01**	**10928**	**3320**	**76998**	**43**
2HL1PA	41.55	12.68	3803	142	BDL	7187	1737	133242	12
2HL1PB	36.82	12.69	3255	136	BDL	7229	2240	119635	17
2HL1PC	38.34	12.67	3177	131	BDL	6208	2059	138827	21
2HL1P Average	**38.91**	**12.68**	**3412**	**137**		**6875**	**2012**	**130568**	**17**
2HL2PA	36.12	12.65	2657	118	BDL	7463	1987	128798	11
2HL2PB	39.26	12.70	2942	111	BDL	5563	1915	144154	9
2HL2PC	39.30	12.68	2498	100	BDL	5666	2154	148989	13
2HL2P Average	**38.23**	**12.68**	**2699**	**110**		**6231**	**2019**	**140647**	**11**
2AL½PA	47.66	8.60	9825	1071	BDL	10570	2718	113632	1436
2AL½PB	60.96	8.55	7554	807	BDL	10985	2850	147508	1909
2AL½PC	52.86	8.62	8470	1071	BDL	11909	2785	120942	1739
2AL½P Average	**53.83**	**8.59**	**8617**	**983**		**11155**	**2785**	**127360**	**1695**
2AL1PA	72.86	8.66	3962	813	BDL	11283	3212	139127	1929
2AL1PB	54.15	8.24	9354	818	BDL	8525	2180	170099	1658

Sample code	% Solids	pH	Total Kjeldahl N	Ammonium -N	Nitrate-N	Total P	Total K	Ca	Water extractable P
2AL1PC	59.20	8.90	5333	705	BDL	13064	3249	127705	1644
2AL1P Average	**62.07**	**8.60**	**6216**	**779**		**10957**	**2880**	**145644**	**1744**
2AL2PA	69.06	8.68	4961	802	BDL	9912	2544	155240	1765
2AL2PB	71.56	8.84	3226	497	BDL	3432	947	213582	1514
2AL2PC	69.92	8.73	5631	674	BDL	6936	1762	185573	1656
2AL2P Average	**70.18**	**8.75**	**4606**	**658**		**6760**	**1751**	**184798**	**1645**

BDL is the Below Detection Limit of nitrate-N in slurry materials.

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