Preliminary Report

Critique of the BCRET Project Evaluating the C&H Hog Farm Impact on Big Creek

Report to BRWA

By Michael D. Smolen

Submitted November 7, 2019

The BCRET Project was developed by UA as a research and extension project addressing environmental objectives and production-related waste management technologies. The project ran for five years, providing technical assistance to the C&H hog operation while simultaneously attempting to monitor the environmental impact of the operation on Big Creek, a tributary to the Buffalo River. The following preliminary conclusions are based on information presented in BCRET Quarterly Reports, because the final report was not yet available.

Summary of Opinions

The research elements of the BCRET sought to answer questions concerning the impact of environmentally sensitive management of swine wastes on water quality of Big Creek. The following list of opinions are the essential points of my critique.

Opinion 1. Most of the Phosphorus loading to Big Creek from waste application fields is transported in elevated stream flow from the largest storms. The BCRET project was not very effective, however, in sampling the largest flows. Missing the largest storms is likely to produce an underestimate of Total Phosphorus losses.

Opinion 2. Total Phosphorus concentration increases with stream flow, and this relationship is stronger at the downstream station than at the upstream station, supporting the conclusion that C&H is the source of Phosphorus in the Big Creek watershed.

Opinion 3. Nitrate-N concentration is significantly higher below the C&H facility, and concentration declines as flow increases, suggesting transport of Nitrate is dominated by a subsurface process. This relationship, too, is stronger below C&H, suggesting C&H is the source.

Opinion 4. Regional analysis conducted by BCRET suggests that impacts shown in the data are merely the result of the extent of pasture area compared with forested area. This analysis appears to obfuscate the stronger conclusion that waste application by C&H significantly degrades the quality of Big Creek. This was addressed very well by Peterson (2018).

Opinion 5. In selecting fields 1, 5a, and 12 for intensive study, the BCRET team avoided those fields most heavily used for waste disposal (Fields 7, 9, and 17).

Opinion 6. Field 12 is one of the more heavily used fields, but the flume location on Field 12 is particularly poor as half the flume catchment is buffer area, which provides excessive dilution and makes this field less comparable to the heavily used fields that handle the bulk of C&H wastes.

Opinion 7. The control field for edge-of-field study, Field 5a, was not a good comparison because it was fertilized by commercial fertilizer, with the Phosphorus rate higher than recommended by UA Soil tests. A better control would have been achieved by applying only Nitrogen.

Opinion 8. Subsurface investigations, Electrical Resistivity Imaging and Ground Penetrating Radar reveal that the application areas along Big Creek are not suitable for high volume waste application because of the presence of buried gravel deposits, karstic and epi-karstic features that are likely to conduct leachate directly to Big Creek through preferential flow processes.

Opinion 9. Subsurface piezometer investigations were well-intended, but piezometer studies were never completed. The piezometer sampling could have provided very useful information.

Opinion 10. Grid soil sampling on Fields 1 and 12 and field sampling on the other C&H fields indicate a substantial build of Soil Test Phosphorus, as I predicted in previous reviews. High Soil Test Phosphorus soils could be a continuing source of Phosphorus to Big Creek for many years.

Opinion 11. Sampling of the ephemeral stream and house-well both suggest there may be nitrate contamination from hog manure sources. The results, however, are difficult to interpret definitively due to lack of controls.

Opinion 12. Investigation of leakage from the holding ponds has not yielded any definitive result except to show that such leakage is possible. The cutoff trench installed below the holding ponds has not shown any significant leakage to date, but it is possible that such leakage could bypass the trench, or leakage may be a very slow process. The ERI study (Fields & Halihan, 2016) and drilling of a single well for geologic core sampling adjacent to the waste holding ponds did not fully answer the question (Harbor Environmental, 2016).

Opinion 13. Although five years seems a long time for this study, I recommend continuing this investigation at the existing field sites. A continuing effort would allow development and testing of models to evaluate runoff and subsurface losses from waste application at other locations and under different weather conditions.

Overview

This report is titled “preliminary” because it was based on information available to me in BCRET Quarterly Reports and other publications before the BCRET Final Report was published. I have tried to address primarily issues that will be carried from Quarterly Reports to the Final Report, such as avoidance of the most active fields when selecting runoff monitoring sites, missing data from the largest storms, and inadequate monitoring of ground water impact.

The research proposed by the BCRET team was limited in its objectives. As stated in the Plan of Work, these objectives are “...to evaluate the sustainable management of nutrients from the C&H Farm operation…”, with the following specific tasks:

Task 1. Monitor the fate and transport of nutrients and bacteria from land-applied swine effluent to pastures.

Task 2. Assess the impact of farming operations (effluent holding ponds and land-application of effluent) on the quality of critical water features on and surrounding the farm, including springs, ephemeral streams, creeks, and ground water.

Task 3. Determine the effectiveness and sustainability of alternative manure management techniques including solid separation that may enhance transport and export of nutrients out of the watershed.

Task 1 is a generalized research objective to look at fate and transport of nutrients and bacteria from effluent applied to pastures. It does not commit to evaluate *all* pastures where C&H applies effluent or to the overall evaluation of the C&H facility. The edge-of-field runoff stations, automatic samplers, grid soil sampling, and physical investigations (Ground Penetrating Radar, Electromagnetic Resistance Imaging surveys, and grid-soil sampling) may provide valuable data, but do not answer the question of impact on Big Creek or the Buffalo River. The subsurface transport investigation (piezometers) was not completed, and the grid soil sampling study needs to be supplemented with data on forage harvesting and grazing management. The edge of field runoff sampling study, too, has issues that make interpretation difficult. These are discussed in a later section.

Task 2 appears to address the specific issues of the C&H impact on nearby water features, but as configured this task is not very realistic and is not well controlled. It includes a study of the impact of holding ponds and land application on springs, ephemeral creeks, and ground water. Achieving its objective would require every element of the plan to function perfectly and a longer period of record. It would also require more information and assistance from the landowners for full access and full detail on manure spreading, cattle feeding, etc. Finally, evaluation of the results requires consistent, reliable control sampling areas for comparison. Although the team attempted to address the elements specified in the work plan, ground-water monitoring was not completed, many of the largest storm events were not sampled, and the fields that received the most effluent were not included in the study.

Task 3 addresses improving the practices of the C&H Hog Farm and the Hog Industry. It has little bearing on the perceived objective of determining if C&H is damaging to the environment.

Basis for Opinions

Opinion 1. Most of the Phosphorus loading to Big Creek from waste application fields is transported in elevated stream flow from the largest storms. The BCRET project was not very effective, however, in sampling the largest flows. Missing the largest storms is likely to produce an underestimate of Total Phosphorus losses.

Basis:

The project was set up with only one reliable flow gaging station on Big Creek, downstream from the C&H Farm (USGS 07055790 Big Creek Stream Gage near Mt. Judea, AR). Although BCRET quarterly reports mention flow gaging at the upstream station on Big Creek, it is not clear that flow gaging was accurate at this sampling station. Likewise, flow data are not presented for the culvert or the ephemeral creek sampling sites. The presence of continuous gaging at Mt. Judea, however, is very useful, not just to calculate loads and flow-weighted mean concentrations, but also to distinguish storm flow from base flow. It appears that the location of sampling stations other than the USGS gaging station were not good locations for flow gaging.

Results from Big Creek water samples were presented in quarterly reports as *base flow*, *storm flow*, *grab*, or *storm flow grab* samples. After March 31st, 2014, samples noted as storm flow were collected by automatic, flow-initiated ISCO water samplers, composited proportional to flow. (Note measurement of flow at the upstream sampling station may not be very accurate.) Base flow samples and grab samples were obtained by dipping a sample container in the water by hand on a weekly schedule. Stormflow grab samples, I assumed, were storm-flow samples obtained by hand. Locations without accurate flow gages are not well-suited to estimation of load, and the basis for compositing ISCO samples may be inaccurate.

Samples were labeled as storm flow or base flow by BCRET based on the following criteria:

> Base flows were assessed by lower, level plateaus of the hydrograph curve, while storm flows were determined by sharp, elevated peaks within the hydrograph. Intermediate flows were determined as being between base and storm and located mid-slope as storm flows descended to base flows on the curve. If the hydrograph for a certain sampling event had pronounced peaks, but did not vary significantly in discharge, the resulting flow was characterized as base flow. (January to March 31, 2017 BCRET Quarterly Report p 61)

By this procedure BCRET determined there were 21 storm-flow samples and 102 base-flow samples at the Big Creek downstream station. The absence of an accurate stream flow gage at all but the USGS site makes these criteria questionable in all but extreme cases.

I reviewed the daily mean stream flow records from the USGS stream gage website for the Mt Judea (USGS). *Table 1* shows the record of all flows sampled with their TP and Nitrate-N concentration along with the stream flow at the USGS gage. USGS records show that mean daily flow varied from less than 1 cfs (cubic foot per second) to more than 4,000 cfs during the period April 28, 2014 to June 30, 2019. Using a simple criterion, I considered mean daily flow greater than 100 cfs to be elevated flow (similar to storm flow). In this period there were 343 days with mean daily flow above 100 cfs. Five samples from flow less than 100 cfs were labeled storm samples, and six from samples much greater than 100 cfs were labeled base flow samples.

Figure 1 shows the distribution of samples with respect to flow regime. It indicates good coverage of flows in the low to intermediate range (up to about 300 cfs), but not so good at high flows. The full record shows that elevated flows frequently went on from two to five days and peak flows were often missed, even when the automatic samplers were operating. BCRET took samples (storm, base, grab, or storm grab) on only 37 of the days with elevated flow, and only nine grab samples were taken when mean daily flow exceeded 500 cfs.

Table 1.
Days with mean daily flow greater than 100 cfs and a water sample, sorted by flow at Mt Judea USGS Stream Gage. Discharge, Total P, and Nitrate concentration in mg/l are shown from samples taken at upstream and downstream sampling stations.

			Downstream		Upstream	
date	flow cfs	label	TP	NO3	TP	NO3
8/3/2017	3.67	storm	0.032	0.185		
10/13/2019	10.9	Storm	0.03	0.39	0.021	
6/29/2019	51.7	Storm	0.748	0.147	0.028	0.076
8/24/2019	54.5	storm	0.126	0.182		0.055
6/22/2019	82	Storm	0.032	0.136	0.03	0.14
2/15/2017	105	Grab	0.082	0.159	0.06	0.177
4/8/2019	116	grab	0.022	0.091	0.014	0.132
3/1/2018	122	grab	0.035	0.337	0.032	0.06
3/15/2019	124	grab	0.036	0.18	0.032	0.226
4/26/2018	133	grab	0.029	0.081	0.022	0.124
2/24/2016	134	baseflow	0.058	0.142	0.052	0.057
6/1/2015	139	Storm	0.05	0.109		0.099
3/19/2015	140	baseflow	0.028	0.234	0.024	
1/3/2019	143	grab	0.008	0.323	0.006	0.111
7/6/2015	145	Storm	0.275	0.204		0.182
5/14/2015	168	baseflow	0.05	0.326	0.046	
3/11/2015	183	storm	0.3	0.209	0.026	0.177
5/8/2015	183	storm	0.544	0.292	0.354	0.118
4/6/2017	189	grab	0.034	0.173	0.038	0.34
10/13/2014	191	storm	0.028	0.379	0.058	0.099
11/18/2015	220	baseflow	0.05	0.334	0.046	0.147
4/15/2015	224	storm	0.048	0.166	0.04	0.229
6/25/2019	249	grab	0.032	0.255	0.023	0.09
2/13/2019	276	storm grab	0.027	0.349	0.022	0.144
5/18/2015	291	storm	0.04	0.209	0.034	0.204
6/6/2019	343	grab	0.017	0.279	0.015	0.11
4/25/2019	381	grab	0.065	0.208	0.051	0.115
5/13/2014	396	storm	0.086	0.133	0.062	0.109
2/22/2018	409	grab	0.05	0.499	0.043	0.096
6/6/2017	418	storm	0.118	0.073		0.358
5/1/2017	446	grab	0.032	0.279	0.026	
7/9/2015	466	Base flow	0.05	0.117	0.048	0.144

			Downstream		Upstream	
date	flow cfs	label	TP	NO3	TP	NO3
5/26/2015	486	BASE	0.2	0.096	0.044	0.087
3/26/2015	531	storm	0.076	0.144	0.064	0.08
3/29/2018	568	grab	0.079	0.016	0.037	0.09
5/2/2019	581	grab	0.056	0.145	0.047	0.169
11/1/2018	589	grab	0.079	0.368	0.056	0.103
5/3/2018	646	grab	0.065	0.095	0.305	0.268
5/30/2019	744	grab	0.179	0.138	0.123	0.106
4/18/2019	752	grab	0.046	0.173	0.14	0.115
6/5/2017	807	grab	0.064	0.185	0.054	0.113
5/11/2015	4010	storm	0.53	0.071	0.074	0.114

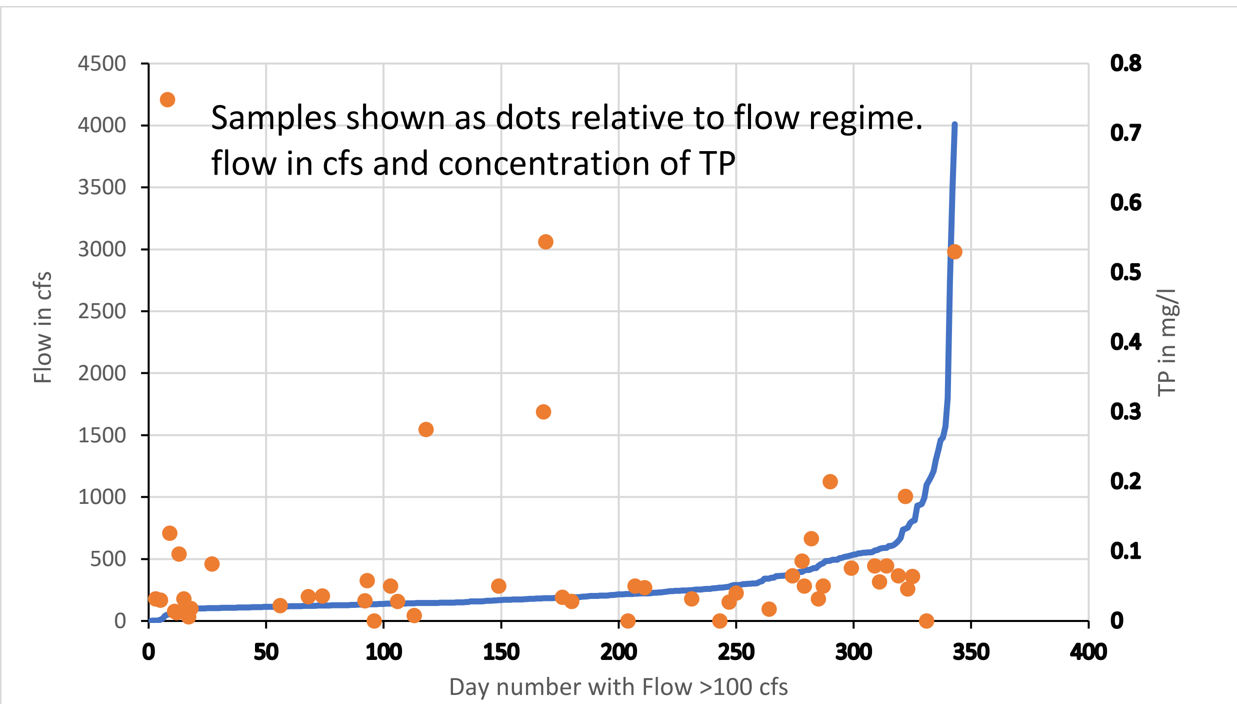

Figure 1. Analysis of sampling coverage of flows with mean daily discharge greater than 100 cfs. Shown is concentration of TP in samples from the downstream sampling site on Big Creek and the mean daily discharge at Mt Judea USGS gage.

Opinion 2. Total Phosphorus concentration increases with stream flow, and this relationship is stronger at the downstream station than at the upstream station, supporting the conclusion that C&H is the source of Phosphorus in the Big Creek watershed.

Basis:

Figure 2 shows the relationship of concentration of TP versus flow at the upstream and downstream stations. Note the steeper slope at the downstream station compared with upstream. This suggests stronger influence of flow on concentration, typical of a surface washoff transport mechanism. Variation of TP concentration at the low flow end of the graph may be explainable by waste application to fields or other factors not recognized in the BCRET reports. No analysis of application and rainfall timing effect on concentration was presented.

Opinion 3. Nitrate-N concentration is significantly higher below the C&H facility and concentration declines as flow increases, suggesting transport is dominated by a subsurface process. This relationship, too, is stronger below C&H, indicating C&H as the source.

Basis:

Figure 3. shows the analysis for Nitrate-N concentration versus flow. As expected, Nitrate concentration decreases with flow, suggesting a subsurface route of transport. Once again, the higher values are at the downstream station, near the sources of effluent application. Nitrate-N concentration may be influenced by season as well as land use.

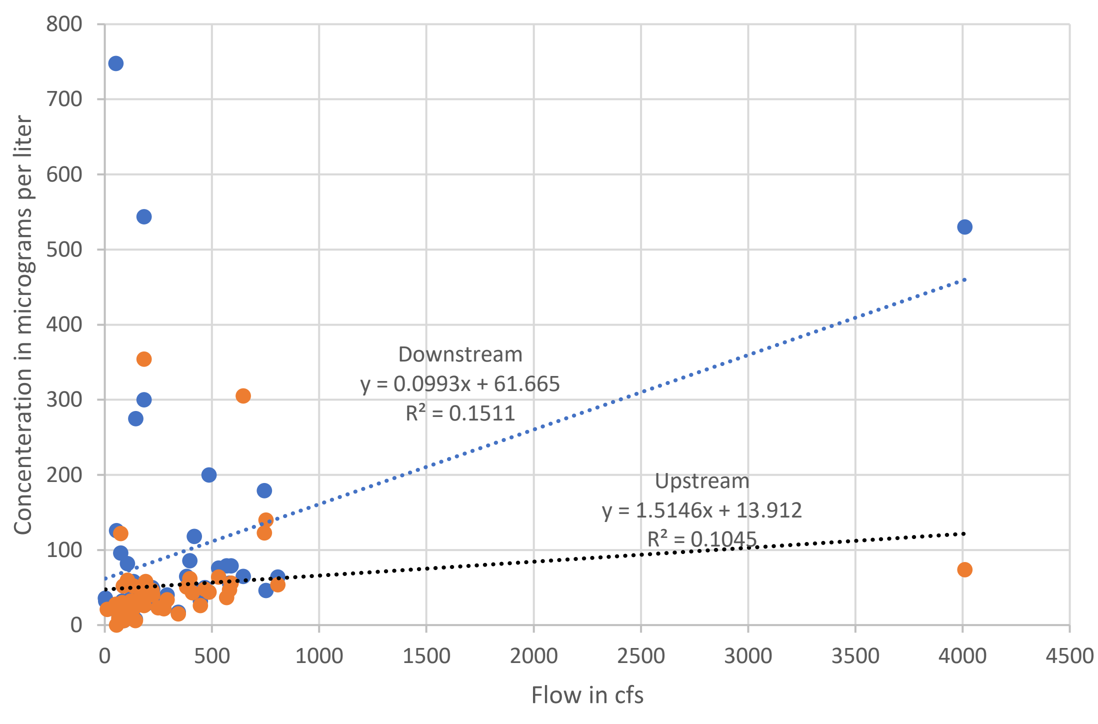

Figure 2 Concentration of TP upstream and downstream versus flow at Big Creek station. Concentration is in micrograms/l.

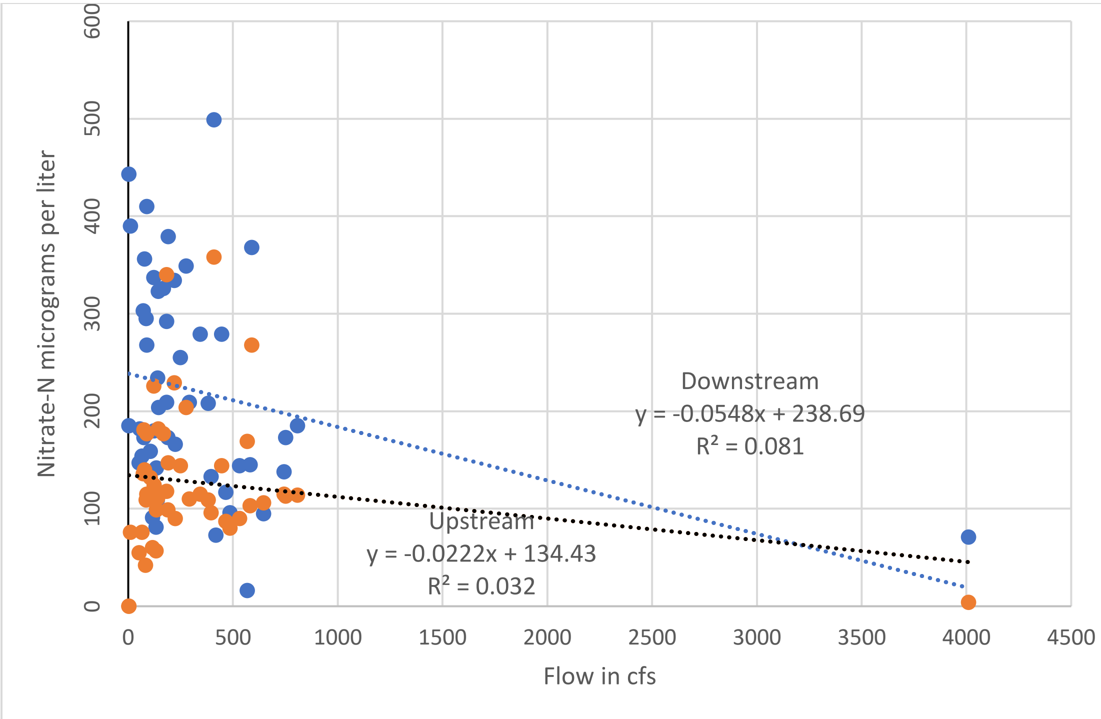

Figure 3. Regression of concentration of Nitrate-N versus Flow at upstream and downstream stations on Big Creek. Flow from Mt Judea USGS gage. Concentration is in micrograms/l.

Opinion 4. Regional analysis conducted by BCRET suggests that impacts shown in the data are merely the result of the extent of pasture area compared with forested area. This analysis appears to obfuscate the stronger conclusion that waste application by C&H significantly degrades the quality of Big Creek. This was addressed very well by Peterson (2018).

Basis:

This conclusion relates to the regional analysis presented in the April 1 to June 30 BCRET Quarterly Report (p 40-55), "Relating Land Use and Nutrient Concentrations in Streams of Ozark Mountain Watersheds." The comparisons offered by BCRET, the Illinois River and Beaver Lake, (reproduced here in Figure 4) have much higher involvement of fertilized pastures than does the Big Creek watershed, either upstream or downstream. This analysis places both stations of Big Creek at the low end of the graph, deemphasizing the differences between upstream and downstream. Further, the Big Creek observations of BCRET are relatively insensitive to the impact of the C&H facility because of the large dilution from forested areas.

Peterson (Peterson, 2018) conducted similar analysis with more extensive statistical analysis. I fully support Peterson's conclusions. Peterson points out that the differences between upstream and downstream TP and Nitrate behavior are not explainable by the analysis used by BCRET, but that the results are indicative of the larger influence of C&H farms. I agree with this assertion.

.

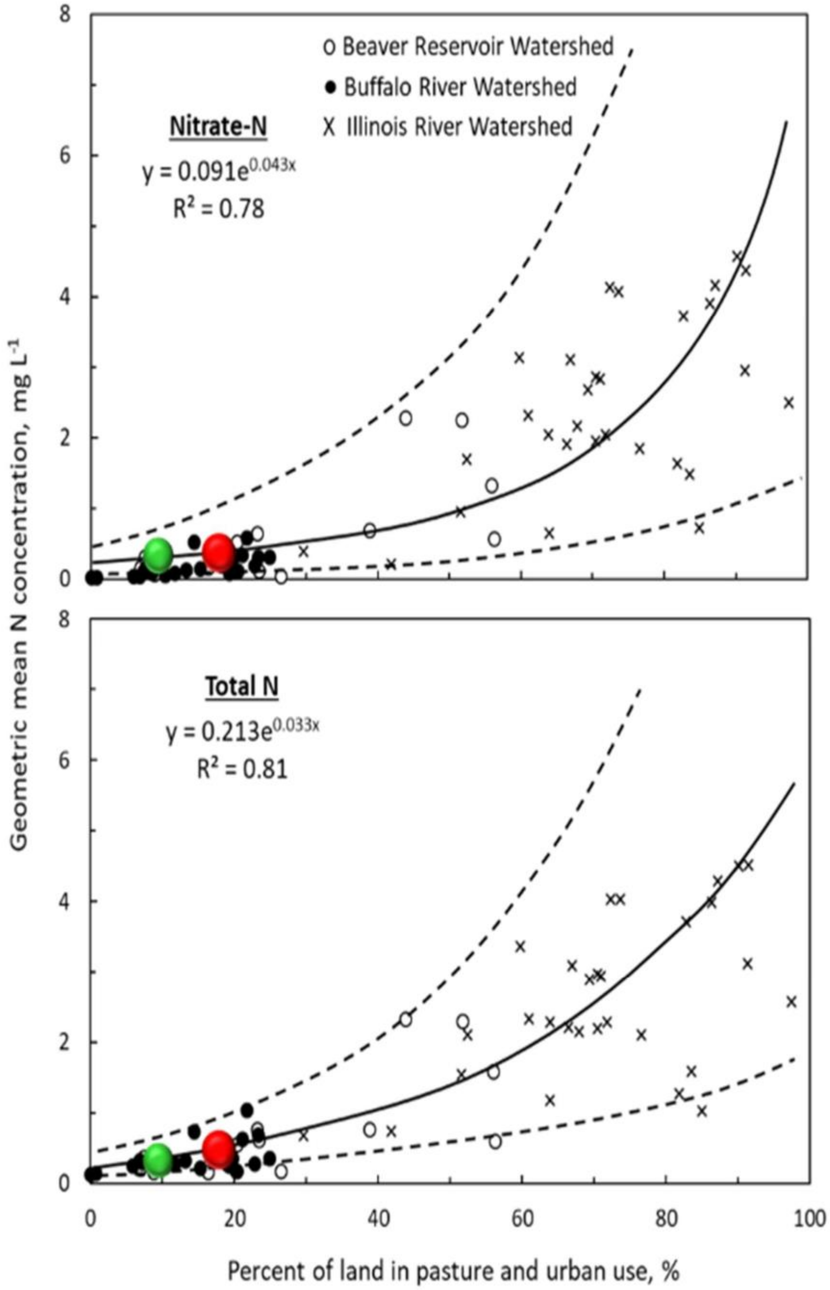

Figure 4. Extract from BCRET Quarterly Report April - June 2017, P 53 *[Figure 15. Relationship between land use and the geometric mean nitrate-N and total N concentrations in (mg L^{-1}) in the Buffalo River, Upper Illinois, and Upper White River Watersheds. Dashed lines represent the 95% confidence 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]*

Opinion 5. In selecting fields 1, 5a, and 12 for intensive study, the BCRET team avoided those fields most heavily used for waste disposal (Fields 7, 9, and 17).

Basis

In selection of fields for extensive study, the BCRET team seems to have avoided the fields most heavily used for waste disposal (Fields 7, 9, 10, and 17). As shown in *Table 2*, Field 12 and Field 1 were used more heavily in 2016 and 2018, when application to field 7 was reduced because of high API. Most of the waste produced by C&H was applied to Fields 7, 10, 13, and 17.

Field 1 was one of the more upland, sloped areas, while Field 12, was more like the bottomland fields, along Big Creek.

Table 2 Rate of waste application on selected fields

Field	**2014**	**2015**	**2016**	**2017**	**2018**
			Gallons/acre		
1*	6301	6575	10685	8219	7808
7	6162	15319	0	11757	9938
9	2924	6085	13521	9746	10169
10	8505	16485	10341	8294	9829
12*	4404	8158	13684	7895	9211
17	9240	14044	14483	12226	10627

*Field selected for edge of field study

Opinion 6. Flume location on Field 12 is particularly poor as more than half the flume catchment is buffer area, which provides excessive dilution and makes this field less comparable to the heavily used fields that handle the bulk of C&H wastes.

Basis

Area details of the three edge of field study areas are shown in *Table 3*. Field 1 is smaller than planned in the Plan of Work (less than 2 acres). It has enough slope to allow reasonably accurate runoff measurement with the type of installation used. Less than 10% of the area closest to the flume is buffer (i.e. no waste application). This seems to be a good installation. The map of Field 1 shows the catchment area to be right down the center of the application area. This too is good, but this narrow shape may be a problem in determining the exact catchment area.

Field 12, on the other hand, is a large field 28 ac with a small section (0.84 ac) designated as catchment for the flume. In addition to this being much smaller than planned in the plan of work, about one-half the catchment area is buffer and likely to produce excessive dilution. It is further worrisome that the catchment area is entirely on the edge of the field, where applications are not likely to be typical of the general management. Slope of this field is quite low making boundaries somewhat uncertain, and the field is subject to flooding in large storm conditions.

Table 3 .

Area of Fields 1, 5a, and 12 monitored for surface runoff, area of flume catchment, area of buffers where no slurry is applied, and area of flume receiving slurry (from BCRET Surface Runoff Report)

Site	Field area	Flume catchment area	Buffer	Flume catchment area minus buffer	Flume catchment receiving slurry
	acres	acres	acres	acres	%
Field 1	15.6	1.76	0.15	1.61	91.4
Field 5a	23.5	9.58	0.54	9.04	0 1
Field 12	28.7	0.84	0.48	0.36	43

The area of each catchment is extremely important in calculating pollutant loading in field runoff. For this reason, field surveys must be done with care. Inf act it is generally recommended that an artificial berm be established around the perimeter of small areas. This assures that small changes such as erosion or compaction due to vehicle traffic or cow trails cannot change the catchment area.

I checked some of the calculations of runoff amount to see if things were reasonable and found some questionable results. Table 4, page 50 of the BCRET Surface runoff report shows runoff amount of 1,016,137 gal/ac from Field 12 in a single storm of May 11, 2015. This would be 38.35 inches of runoff! Field 1 did not record runoff on May 11, 2015. Field 5a recorded 538,621 gal/ac or 19.8 inches, also a rather large amount, possibly higher than the rainfall.

The total period of record for the edge of field studies ranged from 24 to 27 months. It is recommended that such studies be continued 5 years or longer. Fortunately for BCRET, this study did receive a wide range of runoff events in the two years. The biggest problem with the short period of record is the number of equipment failures that degrade the data set.

Concentrations of TP and other constituents covered a very wide range of flows and concentrations. Rather than smoothing the data to remove variation, the sources of variation should be analyzed more fully. Factors such as storm type, season, soil test data, cover conditions, grazing management, and land application history may provide important explanations much of the variance. A deeper study of these factors could improve waste application in the future.

Opinion 7. The control field for edge-of-field study, Field 5a, was not a good comparison because it was fertilized by commercial fertilizer, with the Phosphorus rate higher than recommended by UA Soil tests. A better control would have been achieved by applying only Nitrogen. .

Basis

High rates of commercial fertilizer were applied to Field 5a, in place of applying wastes. However, included N, P, and K, where no P was recommended by UA soil tests.

Opinion 8. Subsurface investigations, Electrical Resistivity Imaging and Ground Penetrating Radar revealed that application areas along Big Creek are not suitable for high volume waste application because of the presence buried gravel deposits and karst and epikarst features that are likely to conduct leachate directly to Big Creek through preferential flow processes.

Basis

Studies by a team from OSU ((Fields & Halihan, 2016)) conducted Electrical Resistivity Imaging study of Fields 1, 5a, and 12 late in December 2014 and March 2015. They found significant evidence of nonhomogeneity of the fields with respect to area and depth, providing clear indications of karst and epikarst soils and geology. The results were descriptive of potential subsurface pathways to ground water and/or Big Creek. Significant differences in resistivity attributable to hog waste application were not found, but these studies were early in the swine farm operation.

A USDA-NRCS team ((Berry, et al., 2014) conducted Ground Penetrating Radar (GPR) studies of Field1, 5, and 12. They found evidence of well-drained soils with numerous anomalies, likely to be buried gravel bars. These areas likely to be subsurface pathways to either Big Creek or to the system of fractures and solution channels in the karst areas below.

Opinion 9. Subsurface piezometer investigations were well-intended but were never completed. The piezometer sampling could have provided very useful information.

Basis

A system of well points (piezometers) with water-level data loggers and sampling ports were installed in Field 5 and Field 12 during 2014. The installation was highly sophisticated, with all equipment located below ground to avoid interfering with agricultural operations on the field. If coordinated with the findings of GPR and Eri surveys this was likely to be the most important part of the study, considering how important subsurface transport is in this area. Unfortunately, no data were obtained from this part of the study.

Opinion 10. Grid soil sampling on the fields 1 and 12 and field sampling on the other C&H fields indicate a build of Soil Test Phosphorus as predicted. This could result in a continuing source of Phosphorus to Big Creek for many years.

Basis

Field sampling of all application fields show significant increases in Soil Test P from 2014 through 2018. Average STP increased from 49 in 2014 to 100.4 in this period.

The following opinions (11-13) are based on professional experience and previous discussion.

Opinion 11. Sampling of the ephemeral stream and house well both suggest there is nitrate contamination from hog manure sources. The results, however, are difficult to interpret definitively due to lack of controls.

Opinion 12. Investigation of leakage from the holding ponds has not yielded any definitive result except to show that such leakage is possible. The cutoff trench installed below the holding ponds has not shown any significant leakage to date, but it is possible that such leakage could bypass the trenches or leakage may be a very slow process. The ERI study and installation of a single well did not fully answer the question.

Opinion 13. Although five years seems a long time for this study, I recommend continuing this investigation at the existing field sites. A continuing effort would allow development of models to evaluate runoff and subsurface losses at other locations and under different weather conditions.

i

References

Berry, B., Brye, K., Daniels, M., Vaught, R., Webb, P., & West, L. (2014). *Ground Penetrating Radar for Field 12.* FAyetteville: BCRET and USDA-NRCS.

Fields, J., & Halihan, T. (2016). *Electrical Resistivity Surveys of Applied Hog Manure Sites, Mount Judea, AR.* Stillwatrer: Boone Pickens School of Geology, Oklahoma State University.

Harbor Environmental. (2016). *C&H Hog Farms Drilling Summary.* Little Rock: ADEQ. Retrieved from https://www.adeq.state.ar.us/water/bbri/c-and-h/files/ch-hog-farms-summary.pdf

Peterson, D. (2018). Spatial and Temporal Changes in Nutrient Concenteration in Big Creek near Mt. Judea, Arkansas - Comparison to Other Buffalo River Tributaries.

USGS. (n.d.). *Mt Judea 07055790 Big Creek near Mt. Judea, AR.* USGS. Retrieved from gage https://nwis.waterdata.usgs.gov/ar/nwis/uv/?site_no=07055790&agency_cd=USGS