Comments on the BCRET Final Report

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LITHOCHIMEIA

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The BCRET Project was funded by the State of Arkansas to determine what impact the C&H Hog Farm would have on the environment. The project ran for five years, monitoring its impact on Big Creek, a tributary to the Buffalo River.

The projects had three 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.

Scope of this report

This report addresses Task 2. Tasks 1 is basic research, and Task 3 is an extension education-related task. I covered these tasks in greater detail in my Preliminary Report (Smolen 2019).

The intent of Task 2 was interpreted by the Governor and the public at large as a charge to determine if the C&H Hog Farm degrades surface water, ground water, or soil quality in the Buffalo River Watershed. Specifically, this question asks whether hog farms should be allowed in the Buffalo River watershed. This Research and the Final Report do not actually answer this question directly.

The research undertaken by the Big Creek Research and Extension Team (BCRET) was crafted for mixed objectives: research, technical assistance, and education, on a cooperating farm (C&H Farms). To maintain good relations and promote cooperation with the farm operator, the Team sometimes compromised the research, and generally interpreted their results in a direction favorable to the operator and the hog industry. The BCRET Report seems to have avoided the basic question, focusing attention to more obscure technical analyses and regional comparisons.

The C&H operation generates more than two million gallons of waste each year that must be spread on nearby fields. Nearby landowners take advantage of the free or inexpensive nutrients from the wastes to fertilize fields and produce hay and cattle. Ultimately the research team had little control of factors like rate and timing of wastes applications or selection of the most active fields (see Opinion 5 in Preliminary Report (Smolen 2019).) Further they seem not to have obtained any records of forage harvesting, cattle production, or grazing management, leaving the total nutrient picture incomplete.

[1] (Sharpley, 2020)

In their plan of work, they were expected to gage stream flow above and below the C&H operation, evaluate alternative pathways such as subsurface flow and flow through karstic features, and measure soil chemistry changes. Soil chemistry was evaluated and reported accurately, showing the expected build-up of soil test P. Shallow groundwater and upstream flow gaging were never completed satisfactorily. Upstream flow gaging and subsurface flow monitoring were not installed because of physical problems; the upstream sampling site was not well suited for flow gaging, and flooding of the subsurface monitoring equipment resulted in canceling that element of the program. Consequently, there was less than desired evaluation of these important pollutant transport pathways. Further, when Big Creek flooded (as occurred at least twice in the five-year record of this project), large quantities of pollutants were not accounted. The peak flow of the storm occurring on May 10 -11, 2015 was missed. And the very large storm of December 27-28, 2015 was completely missed.

General Conclusion from review of the BCRET Final Report

The University of Arkansas research and extension team (BCRET) conducted five years of intensive monitoring and technical assistance education with the one and only large hog producer in the Buffalo River watershed (C&H Farms). The work clearly shows an increase in nutrient concentration in Big Creek and a well-documented increase in loading of Nitrogen and Phosphorus. The results suggest that continued operation of a single farm like C&H, even with the best technical assistance available will be damaging to the Buffalo River. The current moratorium on swine CAFOs should be continued, and in my opinion made permanent.

Concerns with the Monitoring

One flow gaging site was established by USGS at Mt Judea[iii]. This site (labeled BC7 in the BCRET reports) has a level of reliability and traceability through the standard operating procedures of the USGS. Reliable flow gaging was not set up set up for the upstream sampling station, BC6, and serious problems seem to have occurred with flow gaging at the other sampling sites. The BCRET reports lack detailed Standard Operating Procedures for sampling and interpretation of sampling results and Quality Assurance documentation. BCRET reports indicate that the field stations had prefabricated H-flumes installed, and the culvert on the ephemeral stream was used for flow control, but the upstream station, BC6, had no flow control and no traceable rating curve developed. Initial estimates of runoff and loading at BC6 and BC7 were seriously in error. It appears that most of the numerical errors in Chapter 7, on Nutrient Loading, were corrected in the revision published in January 3, 2020. Even with the revisions, errors persist, making it difficult to trust some of the detail of the report. Runoff results from Field studies (Chapter 6) still have errors. However, the general picture is credible, showing significant nutrient pollution emanating from the portion of the watershed utilized by C&H for waste disposal.

Conclusions Concerning Loading of Nutrients (Chapter 7)

Conclusion 1. The BCRET research clearly shows that the area where C&H hog wastes are applied contributes substantially more Nitrogen and Phosphorus to Big Creek than the area upstream (above BC6). This result is shown directly by monitoring results throughout the report.

Basis for this Conclusion. The most important finding from this research is that the portion of the watershed between BC6 and BC7, where all the waste disposal fields are located, contributes from 3 to 7% more P and almost 100% more N than would be expected if it were similar to the forested area upstream. These excess nutrients measured in Big Creek can be expected to move on to the Buffalo River.

Table 1 shows my comparison of upstream and downstream loadings based on Table 3, Chapter 7 of the BCRET Final Report. The last column of Table 1 (this report) shows the following:

- The model selected for LOADEST underpredicts flow by 2% based on area.
- The C&H area adds about 20% more Dissolved-P and 7% more Total-P than expected based on area.
- The C&H area adds about 100% more Nitrate-N than expected based on area.
- The C&H area adds about 77% more Total N than expected based on area.

The Team used LOADEST to estimate nutrient loads. It is difficult to follow the explanation of model selection in Chapter 7, but Total P and N values (Chapter 7, Table 1, column 2) seem wildly out of range, and the AIC values, which they say were used for selection, are very similar, particularly after eliminating Models 2 and 9. All the load estimates in column 2 of Table 1 are extremely high (21 million pounds TP from 26,168 acres is 803 lbs/ac TP and 2,746 lbs/ac N).

Table 1.
Percent increase in loading from sampling above C&H fields (BC6) and fields below C&H (BC7)
(computed from Chapter 7 Table 3 of BCRET Final Report - revised)

	Expected increase	2014	2015	2016	2017	2018	Average excess
Parameter	-------------------- Percent increase BC7/BC6------------------------						
Flow*	150	129	151	151	158	151	-2%
Dissolved P	150	173	169	169	169	170	20%
Particulate P	150	136	153	153	159	161	3%
Total P	150	144	158	158	161	164	7%
Nitrate-N	150	282	232	248	243	244	100%
Particulate N	150	193	203	207	211	219	57%
Total N	150	235	216	226	226	231	77%

*Flow and loading should increase 150% based on the area-weighting assumption (66% of watershed above BC6) used in the BCRET Final Report.

Figure 1 shows the comparison of cumulative discharge above and below the C&H farm. Figure 2 and Figure 3 show the comparison of nutrient loading above and below C&H. These figures, after extensive revision from the first version of the BCRET Final Report, appear to be correct. They show that the C&H area contributes substantial amounts of nutrient to Big Creek.

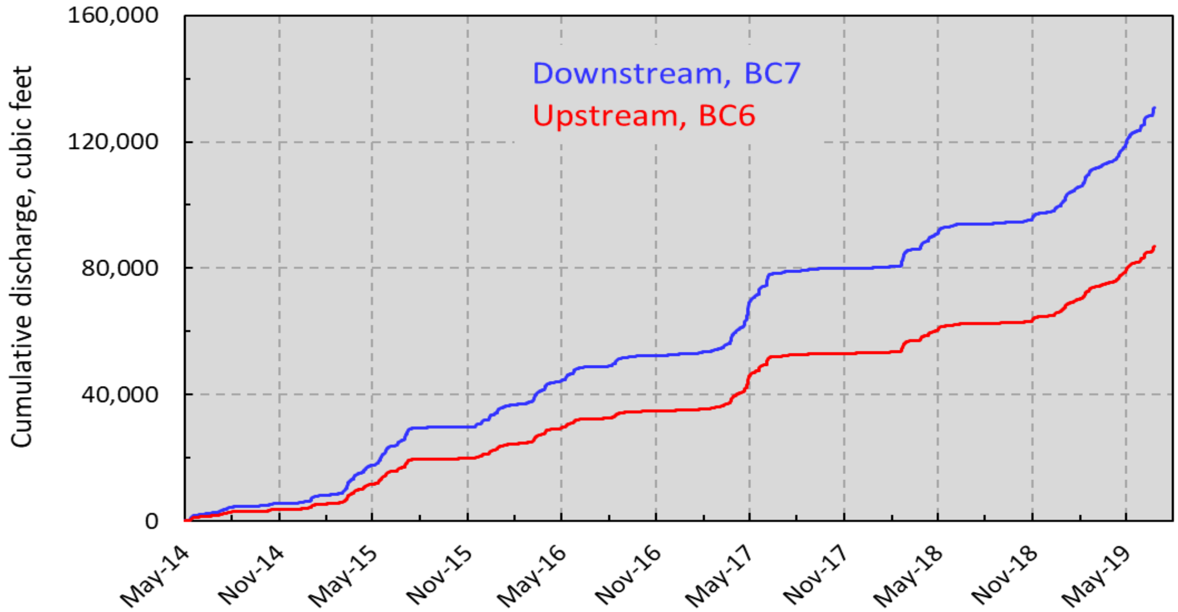

Figure 1. Cumulative discharge at BC6 and BC7 through the project period. (note values on y-axis are off by a factor of 1 million) (from BCRET Final Report)

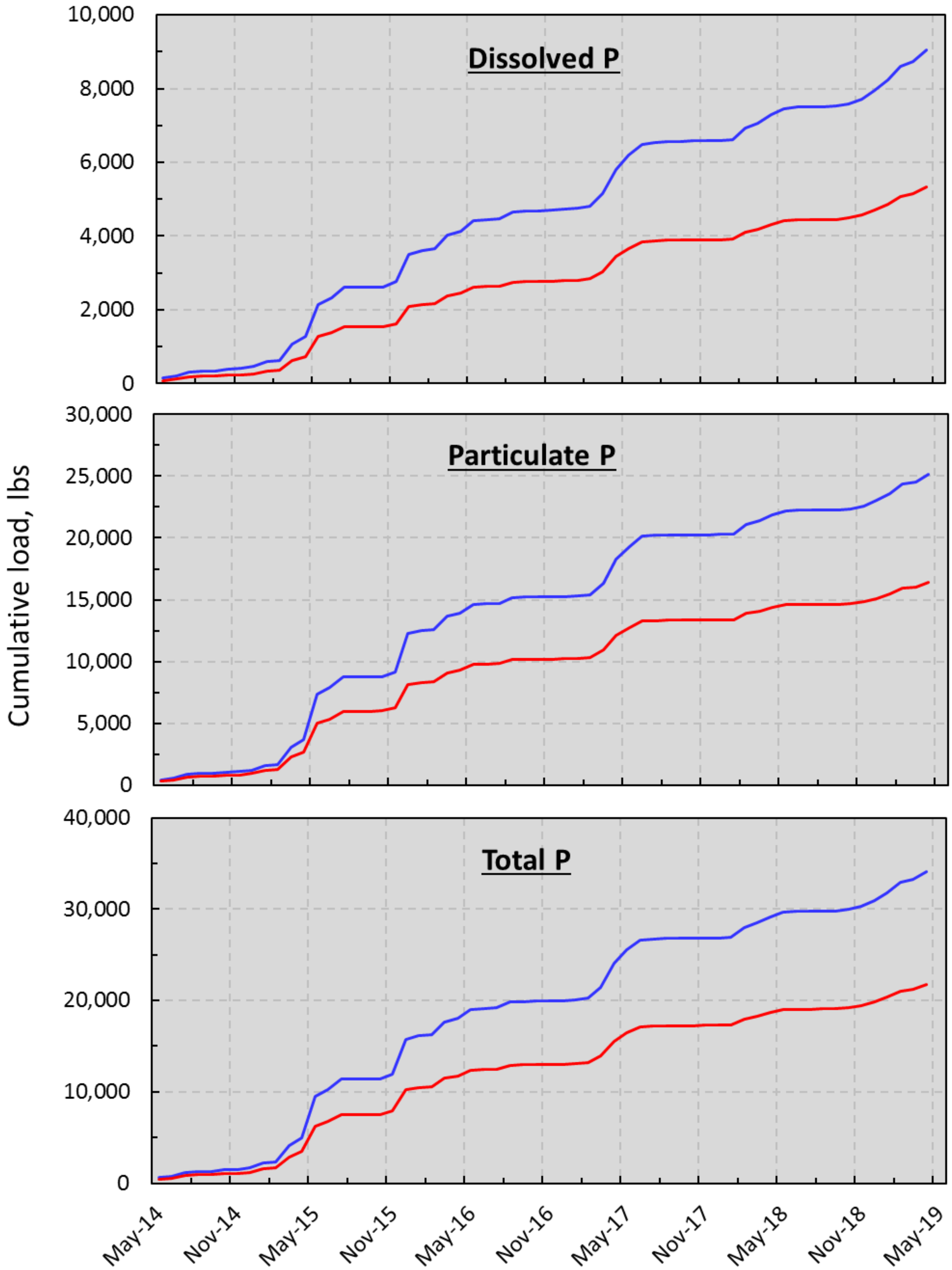

Figure 2. Cumulative loading of Phosphorus at BC6 and BC7. (from BCRET Final Report)

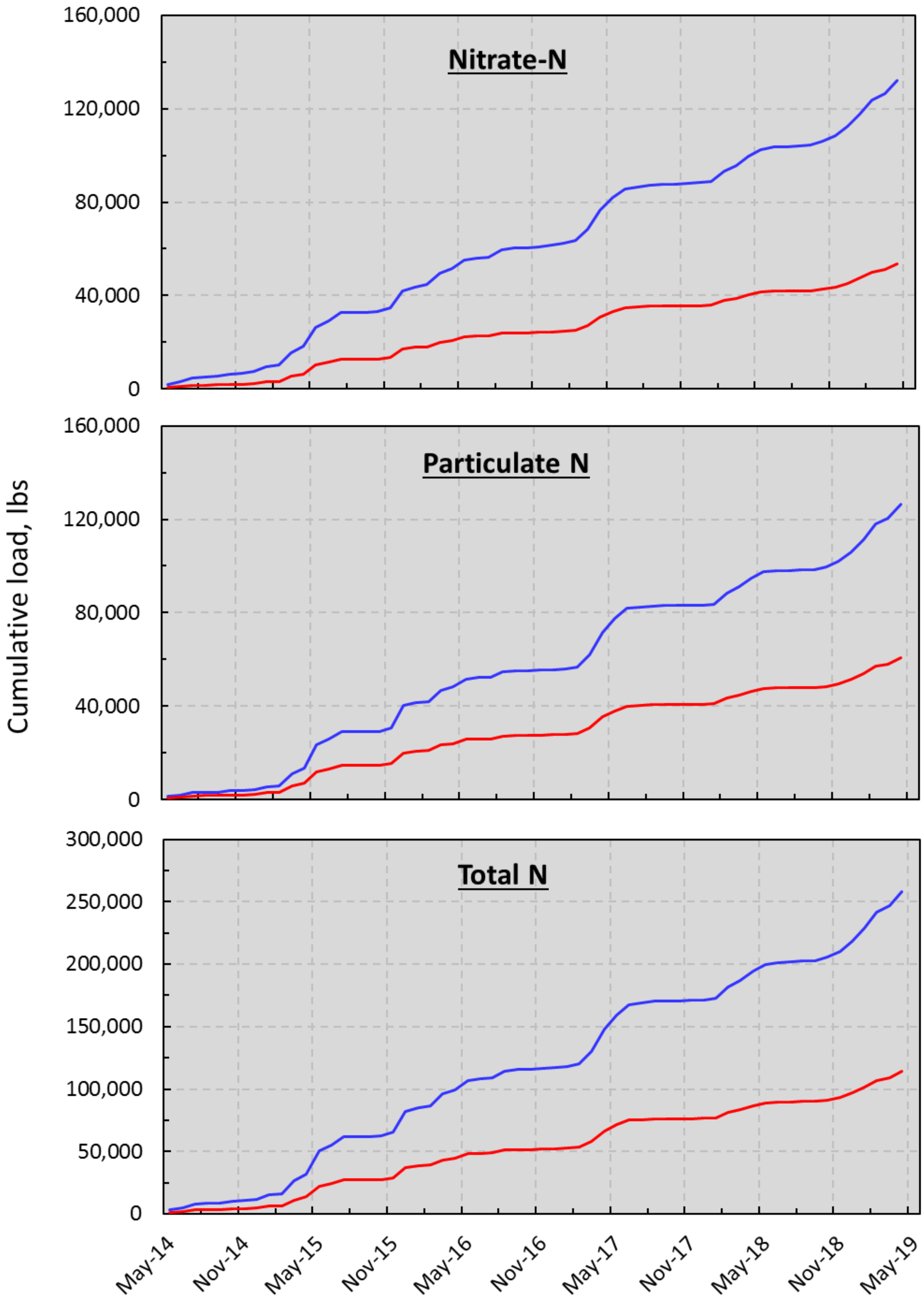

Figure 3. Cumulative load of Nitrogen at BC6 and BC7. (From BCRET Final Report)

Conclusion 2. Nutrient loading from the C&H waste disposal areas is underestimated by this study.

Basis: The Team maintains that the two largest storms of each year account for more than 40% of the total nutrient load (Executive Summary item 13). This estimate is consistent with the findings in other studies, although the BCRET Final Report does not explain how they arrived at this estimate. Never-the-less, the large contribution from storm flow underscores the importance of accurate estimation of flow and concentration of nutrients in large events.

Stormwater sampling was obtained by automatic composite samplers or by grab sampling in the course of periodic grab sampling. The automatic samplers were intended to cover the wide range of flows with flow-weighted composite samples, while the grab samples were point observations of concentration. I saw no documentation of any study to evaluate the performance of the automatic samplers nor any explanation of how grab samples and composite samples were combined to obtain estimates of loading. The data record includes numerous places where the nutrient concentrations from ISCO samplers and grab samples, recorded as the same time, differed by several orders of magnitude. I would like to have seen at least one storm sampled by discrete samples to evaluate the composites. Considering the errors in the first version of the BCRET Final Report, I have little confidence in their estimation of flow at the upstream location or at the field sites.

I would like to have seen some verification of the operation of the ISCO samplers and their accuracy in compositing samples. The description of compositing, with different sample pacing at various stages of flow, complicate the interpretation of the composite sample.

Figure 4 shows the complete record of discharge at BC7 with hundreds of spikes, each of which could be considered a storm event. Many of the spikes (individual events) occurred at very low discharge levels, suggesting they were short duration, with little transport potential. As many as 33 peaks exceeded 1,000 cfs, with one approaching 10,000 cfs. These larger events with their associated periods of elevated flow are the most important for determining total discharge and total nutrient loading.

In the data provided on the BCRET website samples (**Big Creek Water Quality-Final Report** **(Excel)** https://bigcreekresearch.org/project_reports/) **all** samples are classified as either storm or base flow samples. Those captured by automatic samplers are indicated as ISCO storm samples. Many of the storm samples are denoted as grab. As I noted in my Preliminary Report (Smolen 2019), many of the samples notated as Base flow were at elevated flow, and some of the storm samples were at flows that were quite low.

Chapter 8 of the BCRET Final Report includes an analysis of sample concentration as influenced by flow regime (Storm, Base, or Intermediate). Table 3 of the BCRET Final Report shows a significant increase in TP and Nitrate-N at the downstream sampling station (BC7) when looking at the storm flow samples (dropping only 2 questionable outliers). This is shown below in Table 2.

Table 2. Total P and Nitrate-N as a function of flow regime at upstream and downstream sampling stations (adapted from BCRET Final Report, Table 3)

	# Obs.	**Total P**				**Nitrate-N**		
Flow Regime	N	BC7	BC6	P>.05	N	BC6	BC7	P>.05
Base	122	0.027	0.027	NS	123	0.119	0.276	S
Intermediate	50	0.02	0.02	NS	50	0.116	0.253	S
Storm	37	0.063	0.098	NS	38	0.134	0.226	S

In this example, a storm flow sample that made a large difference in mean TP was omitted as an outlier. It is not clear if this may have affected the loading estimates as well. There were more than 50 events exceeding 500 cfs during the 5-year study (Figure 4), but only two were flagged as storm samples in the dataset published on the website. I cannot confirm that the high flow events were included properly. In my opinion it likely this study underestimated stormflow nutrient loading.

Conclusion 3. A Nutrient Management Plan like that in place for C&H would not protect the creek from storms like the larger storms observed in this study.

Basis: The two storms identified by the Team as the largest in this study period were May 11, 2015 (mean daily flow 4010 cfs[Error! Bookmark not defined.]) and December 28, 2015 (mean daily flow 3490 cfs). Each of these events caused flooding on the fields most heavily used for disposal of wastes. The two largest storms in the study period were not extreme events (each had magnitude less than a five-years return period). In other words, application of waste to fields along Big Creek, like Fields 7, 10, and 12 are frequently flooded and likely to contribute more nutrients than predicted here.

The hydrograph for the month of December 2015 is shown in Figure 5. Rainfall for the entire month was approximately 6.95 inches, slightly less than the 25-year, 24-hr storm, used for design of waste holding structures at CAFOs. Pollution from these waste disposal fields is, therefore, more likely than is overflow of the waste holding ponds. Note the December peak storm was not sampled at all.

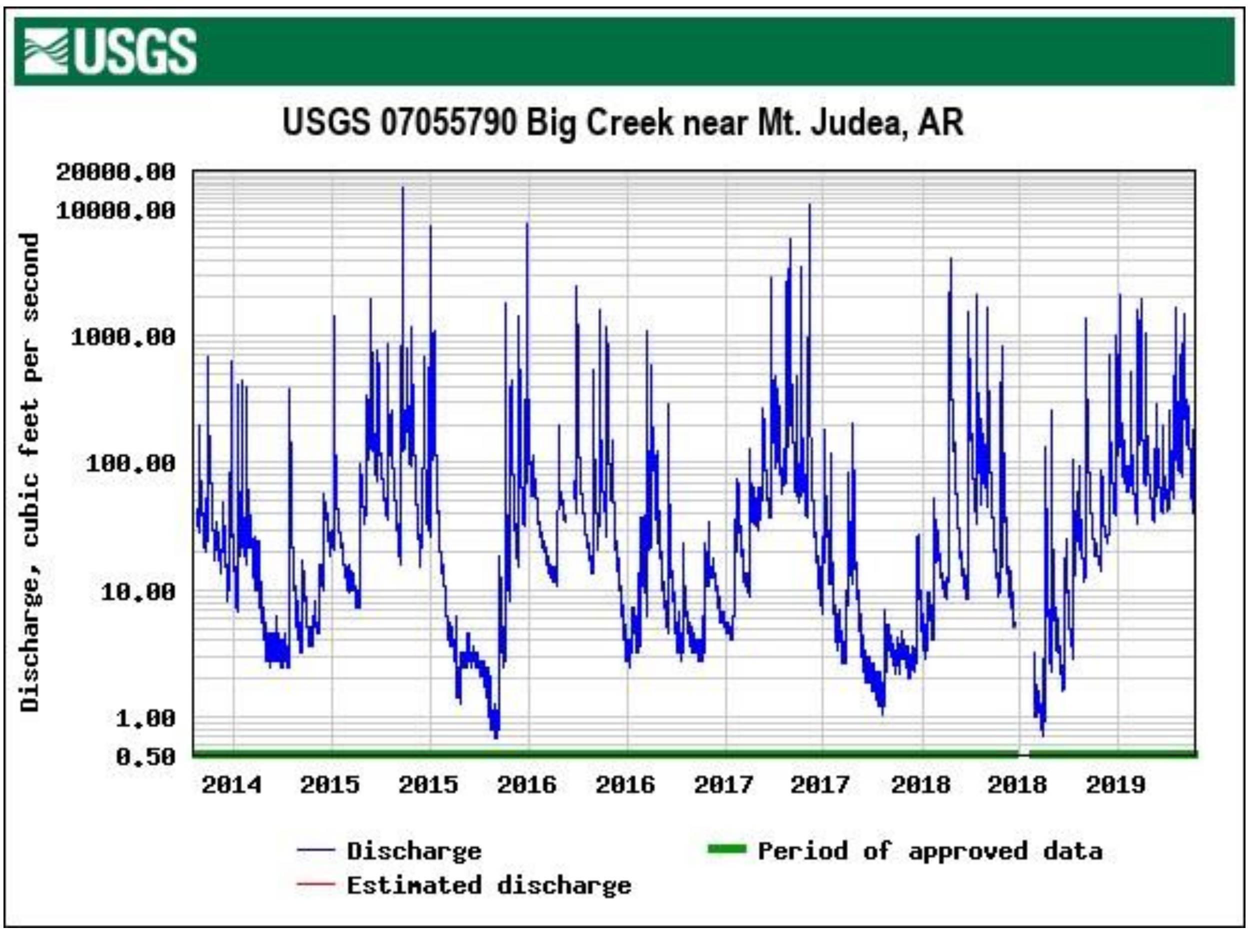

Figure 4. 15-minute discharge record from USGS at the Mt Judea gaging station.

Conclusion 4. The pathway for Nitrate and other non-adsorbed pollutants from the C&H waste disposal fields to Big Creek is largely subsurface, although a considerable amount of Nitrate is washed off the disposal fields in major storm events.

Basis. The most notable outcome of water quality monitoring on Big Creek is the significant increase in Nitrate-N concentration documented below the C&H disposal fields (BC7 5-yr average NO3-N 0.29 mg/L) compared to upstream (BC6 5-yr average NO3-N 0.13 mg/L) (Exec Summary item 13). Further the report notes that Nitrate-N concentration is strongly influenced by streamflow noting

> "…the difference (i.e., downstream was greater than upstream) is very large at low flow and small at high flow. This suggests that at low flows, base flow nitrate-N emerges into Big Creek between upstream and downstream sites and that this base flow has a higher nitrate-N concentration than in base flow above the upstream site." (Exec Summary Item 18),

BCRET further showed the stream loading of Nitrate-N at BC7 is almost double what is predicted based on the upstream water quality (see discussion associated with Table 1, this report).

The BCRET Report presents numerous sophisticated analyses to suggest the Nitrate entering Big Creek between BC6 and BC7 may not be the result of waste disposal on the C&H fields, but all these arguments are weak. For example, in Items 15 through 17 and 19 (BCRET Final Report, Exec Summary), used a flow-weighting model (WRTDS) to smooth the data to suggest there was no increase in Nitrate-N from 2014 through 2019 and no time trend through the period of waste application. However, the WRTDS model has high variance and extremely low R-squared, suggesting a poor fit and inadequate explanation of the variance. Further there is very little reliable data from the period before waste application to support a direct comparison or trend analysis before waste application.

BCRET also confirmed a likely groundwater pathway for Nitrate

> "…a statistically significant (probability <0.0001) increase in nitrate-N concentrations in ephemeral stream (annual mean of 0.760 to 1.152 mg/L for 2014 and 2019) and well samples (annual mean of 0.474 and 0.799 mg/L for 2014 and 2019) over the monitoring period (April 2014 to June 2019), as determined by the Seasonal Kendall's test for trends in nutrient concentrations, at sites adjacent to the swine production facility and holding ponds." (item 10 in Executive Summary, BCRET Final Report)

They make three arguments to reject the obvious conclusion that hog waste is entering shallow groundwater and contributing to streamflow between BC6 and BC7. They say

1. "…it appears that water entering Big Creek from both '…above (BC6) and the intervening subwatershed (BC7) …is similar.' (last sentence in item 18, BCRET Final Report, Executive Summary)"
2. "…Despite higher nitrate-N concentrations at the down than upstream site on Big Creek, the relationship between upstream and downstream concentrations is unchanged over time." (item 19) and
3. "…chloride and electrical conductivity did not exhibit any statistically significant change over the monitoring period in well, ephemeral stream, and trench samples (April 2015 to June 2019)," which they suggest implies… "…elevated nitrate-N concentrations in well and ephemeral stream samples may be influenced by sources other than the holding ponds (i.e., sources that have low chloride and electrical conductivity values).(item 11, BCRET Final Report, Executive Summary)

All three arguments together or individually seem exceptionally weak because (1) upstream and downstream watersheds have similar hydrology and similar geology; (2) the record is too short and noisy to establish a trend; and (3) the deep groundwater, represented by the well may be influenced very differently. Shallow groundwater is clearly linked to Big Creek and may not have the same source as the deep well. Differences in chemistry from the waste holding ponds does not preclude the possibility of leaching from disposal fields.

In addition, it is very likely that the excess Nitrate-N observed at BC7 is the result of local processes such as infiltration from disposal fields and transmission through buried gravel beds and epikarstic features identified by the Ground Penetrating Radar study discussed in great detail in Appendix C (BCRET Final Report).

Conclusion 5. The Regional Analysis presented in Chapter 8 of the BCRET Final Report is not sufficiently refined to draw conclusions concerning the impact of C&H on the water quality of Big Creek or the Buffalo River. It appears to be included in this report to obfuscate the clear finding that nutrient loading increased significantly between sampling stations BC6 and BC7.

Basis. The regional analysis presented in Chapter 8 is interesting but not definitive. It compares a small section of the Buffalo River (the upper and lower parts of Big Creek, BC6 and BC7) with Upper Illinois River and the Upper White River. They find that the mean concentrations of N and P species in the two sections of Big Creek follow the same pattern of increasing concentration with increasing percentage of land in pasture and urban use. The Upper Illinois River watershed and the Upper White River watershed are located in a major poultry producing area where virtually all pastures have long histories of excessive poultry litter application as well as a rapidly growing urban population. Studies in the Illinois River have shown soil phosphorus concentrations often exceeding 300 ppm, more than three times the soil phosphorus currently in the Big Creek pastures. All this comparison shows is that like other watersheds in the region, watersheds with development of pasture fertilized with animal manures and other sources have higher nutrient loss than forested watersheds.

The Team concludes from the regional study that "…a myriad of factors may influence observed nutrient concentrations in streams…" and that "…we need caution when interpreting trends in water quality over databases that only cover a limited timeframe." The Team further noted that "…Big Creek and the downstream watersheds and ecosystems in this ecoregion are low relative to other watersheds in this ecoregion." This is an important point to consider when thinking about increasing hog production or poultry production into the Buffalo River watershed.

Table 3 shows the land use classifications from the regional study. The upstream area (above BC6) has 1,389 acres of pasture (8%), and the downstream area has 1,561 acres (17.8%). These automatically place them in the lowest quadrant of the regional study watersheds, where resolution is poor because most of the forested watersheds are grouped together.

The most significant take-away from the regional study should be that the small number of additional acres of pasture, fertilized by hog slurry resulted in doubling of Nitrate-N concentration. The regional study provides a warning that expansion of production of hogs and/or chickens in or near the Buffalo River watershed would likely push the water quality closer of the Buffalo River closer to that observed in the Illinois River, where water quality has deteriorated substantially

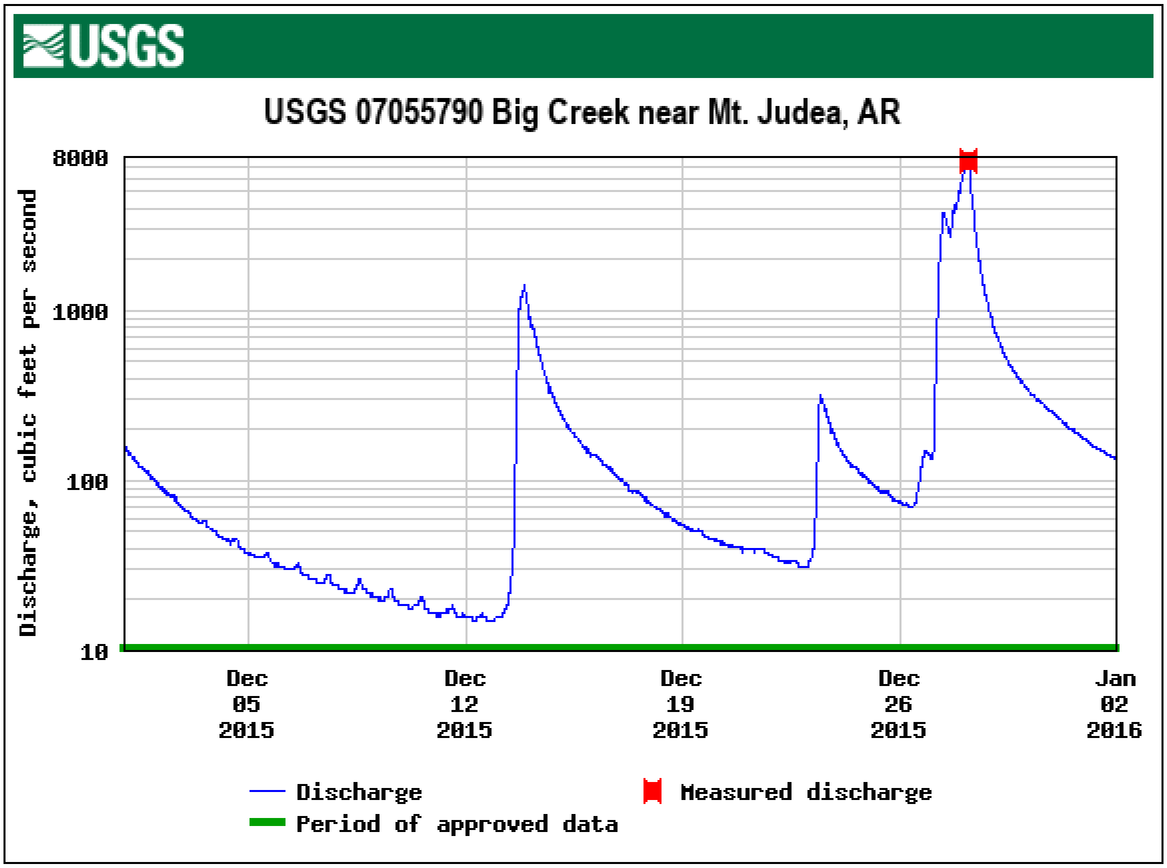

Figure 5. USGS hydrograph for December 2015 at station BC7.

Table 3,
Land use classification of the Big Creek Watershed (Adapted from page 6 of BCRET Final Report Chapter 1)

Land Use	Upstream of C&H		C&H active area		Total Monitored	
	acres	%	acres	%	acres	%
Grassland/Pasture	1,389	8	1,561	17.8	2,950	11.3
Deciduous forest	15,110	86.5	6,570	75.1	21,680	82.7
Evergreen forest	514	2.9	250	2.9	764	2.9
Mixed forest	4	0	11	0.1	15	0.1
Woody wetlands	0.4	0	0.7	0	1	0.0
Open Space	435	2.5	327	3.7	762	2.9
Developed/Low intensity	13	0.1	23	0.3	36	0.1
Developed/medium intensity	0.2	0	4	0.1	4	
Developed/High Intensity	-	-	-	0.1		
Open Water	-	-	0.9	--		
TOTAL	17,471		8,750		26,221	

Conclusion 6. The concentration of soil test phosphorus (STP) in the C&H waste disposal fields is increasing rapidly, as I predicted in my review of the C&H NPDES permit application in 2012 (Smolen 2013) and my subsequent reviews of the Nutrient Management Plan (NMP) submitted annually to ADEQ by C&H. The NMPs developed annually clearly do not account for the actual consumption and removal of nutrients.

Basis. Chapter 4 of the BCRET Final Report shows conclusively that STP increased in each of the two disposal fields (Field 1 and Field 12), grid-sampled repeatedly in 2014, 2016, and 2018. Results are shown in *Table 4*. Field 5a, which received no waste application during the study period but received a comparable quantity of inorganic P-fertilizer. Soil Test P (STP) almost doubled over three years in the application areas, but hardly changed in the buffer areas, of Field 1 and 12. Likewise, there was no significant change in STP in the application area of Field 5a, which received only commercial fertilizer through the period. This confirms the results observed in soil tests throughout the C&H disposal area (reported in C&H Annual Reports to ADEQ).

Table 4. Soil test results for BCRET Field Study 2014-2018

	2014			2016		2018		
	P-sat	STP	Lb/ac 2014-16	P-sat	STP	Lb/ac 2017-18	P-sat	STP
Field 1	%	ppm		%	ppm		%	ppm
Whole field	8.2	59		7.8	57		12.7	91
Application area	8.9	65	106	9.8	73	277	15.8	115
Buffer area	7.4	52		5.4	38		8.9	62
Field 5a								
Whole field	4.6	45		4.0	39		4.9	47
Application area	5.0	50	75	4.0	40	50	4.6	45
Buffer area	3.5	33		3.9	38		5.4	51
Field 12								
Whole field	6.4	63		9.6	104		11.6	122
Application area	5.6	56	119	9.9	107	234	12.0	126
Buffer area	8.9	90		8.6	95		10.5	112

STP is Mehlic-3 extract in parts per million. P-sat is % saturation of P. Field 5a is the control.

Also shown in Table 4 is the percent saturation (P-sat). P-sat increased from 6 to 8% in 2014 to 11 to 12% in 2018. As P-sat increases, the losses to runoff also increase.

The BCRET study evaluated the spatial distribution of the STP increase by sampling on a 50-ft grid displaying the result spatially. It is not surprising they found both a general increase in STP across the field and an extremely high STP increase in the areas where cattle are fed. This result is easily explained by the fact that the cattle were often fed in the same location, promoting loafing and defecation in the same area. If the cattle are in fact managed as indicated in the Nutrient Management Plan (NMP) submitted to ADEQ annually, these fields should have exceptionally high forage production (6 tons/acre) and should be managed with rotational grazing, requiring a very high level of management that keeps the animals moving to consume forage efficiently and distribute manure. The general increase of and the spatial concentration of STP both reveal that the management is much less intensive than that shown in the NMP.

Conclusion 7. Results of Field Runoff studies on Fields 1, 5a, and 12 suffer from serious design and computational errors that have not been addressed to date. Consequently, I have not presented these findings in this report.

Basis. My review of findings of the Field Runoff studies presented in Chapter 4 were presented earlier in my Preliminary Report (Smolen 2019) and are summarized below.

1. 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).
2. Field 1 was one of the more upland, sloped areas, while Field 5a and 12 were more like the bottomland fields, along Big Creek.
3. 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.
4. The map of Field 1 shows the catchment area to be right down the center of the application area. This narrow shape presents a problem in determining the exact catchment area as no berm was installed to assure the boundaries are correct.
5. Field 12 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, 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 very low making boundaries somewhat uncertain, and the field is subject to flooding in large storm conditions.
6. Field 5a is subject to flooding.

I checked some of the calculations of runoff amount to see if things were reasonable and found questionable results. Table 4 (Chapter 5 of the BCRET Final Report shows runoff amount over 1 million gal/ac from Field 12 in a single storm of May 11, 2015. This would be about 38 inches of runoff! Field 1 did not record runoff on May 11, 2015. Field 5a recorded 539,000 gal/ac or 19.8 inches, also a rather large amount, possibly higher than the rainfall. These results are so far from credible, I chose not to review the other results.

Final Considerations

A lot of work and a lot of money went into the BCRET project, and a wealth of data was produced. The data include time series of water quality in Big Creek and information that can help reduce the impact of intensive animal production in the future. The watershed is very large (26,000 acres) and the C&H farm utilizes only about 600 acres, about 2% of the contributing area. Yet the impact of C&H on the water quality of Big Creek is significant. Continued operation of C&H and/or introduction of similar production facilities would be expected to increase the loading to the river and result in long-lasting problems in water quality. The regional study presented in Chapter 9 of the BCRET Final Report provide a glimpse of the likely outcome of continued expansion of animal production into a similar, relatively pristine watershed.

In my review I have hardly touched on some of risks like leakage from waste holding ponds, spills from transport of wastes overflow of holding ponds, or degradation of ground water through the karst geology underlying the area. These risks are not easily quantified and may not become visible for many years. It is important, however, to be aware that animal operations like C&H continually import nutrients in the form of feed, and these nutrients must go somewhere. Less than half the Nitrogen and less than 20% of the phosphorus is exported as meat. The remaining nutrients, coming in day and day out, may leak to surface or groundwater, or they may build up in the soil, increasing the source for future years. Nutrients may be consumed in a growing crop, as expected in the Nutrient Management Plans, but if the crop is not harvested and shipped out, it remains in place to influence water quality into the future. I would particularly note that grazing is not an effective means of removing nutrients, because cows are very inefficient.

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