Buffalo River Watershed Alliance

Attached please find three (3) files submitted by Buffalo River Watershed Alliance as our public comments on proposed revisions to Regulation 5 and Regulation 6. These comments are submitted in addition to comments submitted in the previous comment period. Attached are the following files: (1) BRWA Comments on BCRET Final Report, (2) Preliminary Report on BCRET Final Report, November 7, 2019, and (3) Comments on BCRET Final Report, January 20, 2020. Please confirm receipt of all three (3) files by email response to buffalowatershed@gmail.com. Thank you for the opportunity to comment.

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Comments on Regulation 6 and Regulation 5 Revisions

Submitted via electronic delivery to
http://water.adeq.commentinput.com/?id=6pAef
January xx, 2020

These comments are submitted by the Buffalo River Watershed Alliance regarding proposed revisions to APC&EC Rule 5 Liquid Animal Waste Management Systems, Markup Draft July, 2019 and APC&EC Rule 6 Regulations for State Administration of the National Pollutant Discharge Elimination System (NPDES), Markup Draft July, 2019.

The following are intended as addendums to comments submitted on September 23, 2019 during the previous 30-day comment period regarding these same revisions and we hereby incorporate those comments in their entirety by reference. These comments primarily focus on the Big Creek Research and Extension Team Final Report and on proposed Rule 5.901 and Rule 6.602. Also included below are excerpts from two reports prepared by Dr. Mike Smolen, Ph.D, an acknowledged expert in water quality and agricultural waste management. Both reports are attached to these comments in their entirety and should be considered as part of our comments.

We fully support the proposed changes to Rule 5.901 and Rule 6.602 prohibiting the issuance, reissuance or modification of permits for medium and large swine CAFOs in the Buffalo National River watershed.

Summary

The Big Creek Research Extension Team's (BCRET) final report (https://bigcreekresearch.org/project_reports/) in spite of numerous errors and apparent obfuscation, nevertheless clearly documents, after only 5 years of operation, water quality impacts from a single hog concentrated animal feeding operation (CAFO) in the Buffalo National River Watershed. Such facilities are designed for a much longer operational life. In this case, C&H Hog Farm had an initial 12-year contract and likely would have remained operational for a much longer period if not for the closure of the facility. The documented impacts as detailed below would have grown exponentially if, 1) C&H had been allowed to operate until the end of its design life, and/or, 2) additional medium or large swine CAFOs were permitted in the watershed. Statements and data from the BCRET report, and the conclusions of the expert panel review of the BCRET report, along with the two expert reports attached to these comments, all reveal impacts and advise caution regarding management of swine waste from C&H and warn of the potential impact of other such facilities in the watershed, thus supporting the need for a permanent moratorium on swine CAFOs in the Buffalo National River watershed in order to protect this extraordinary resource water and state and national icon.

It must be noted that this 90-day comment period was opened ostensibly to allow for comments on the BCRET final report, released after the previous 30-day comment period had closed. While our comments here reference the BCRET report, **we contend that the BCRET final report is so rife with errors that the accuracy and reliability of its entire contents and conclusions are called into serious question.** Even the expert review team did not identify numerous errors which only came to light due to careful review by concerned citizens who brought errors to the notice of the BCRET team. Some of these errors are noted below. Some have been corrected in the revised report but others persist. Below in Part 1 are examples of impact to soil and surface and groundwater from operation of the C&H Hog Farm, quoting from the BCRET final report. There follows in Part 2, excerpts from two reports prepared by Mike Smolen, Ph.D, an acknowledged expert in water quality and agricultural waste management. Both reports are attached to these comments in their entirety as part of our comments.

<u>Part 1: Evidence of Impact shown in BCRET Final Report</u>

1. **Application of hog waste onto Buffalo River watershed fields has resulted in phosphorous overloading. (**See page 10 explaining consequences of Legacy Phosphorus and pages 4-6 for graphs from BCRET)

> ***"Future additions of any nutrients (i.e., as mineral fertilizer, swine slurry, or poultry litter) to fields, which received slurry from C&H***

Farms, should be carefully managed, so as not to lead further increases in soil test P. **{7}**

BCRET graphs show: *S*ignificant increase in nitrates and phosphorous downstream from C&H{2}

2. **Karst geology in the watershed leads to significantly increased radius of contamination transport**

   "The Big Creek Watershed below the C&H Farm and application field locations, lie within a karst hydrologic system of great complexity exhibiting intimate connection of surface-water and groundwater regimes. These characteristics endow the hydrologic system as an important recreational resource locally and regionally, but also render the system vulnerable to contamination." {3}

3. **Impaired status of Buffalo River and Big Creek**

   Using BCRET and other water sample data, 19 miles of Big Creek and 14 miles of the Buffalo, at the confluence of Big Creek, were declared 303(d) impaired in 2018**. {4}** See map on page 9 of this document.

4. **Nitrates and Phosphorous increases in Big Creek**

   BCRET acknowledges statistically significant changes in nitrates and phosphorus downstream from C&H:

   "*Phosphorus and N concentrations in Big Creek were greater downstream than upstream of the C&H Farm. For example, the 5-year mean nitrate-N concentration was 0.13 mg/L at the upstream site and 0.29 mg/L at the downstream site.*"

BCRET initially illustrated the downstream increase in nitrate and phosphorus very clearly with the following graphics in Chapter 7, "Nutrient Loads Upstream and Downstream of C&H" {2}:

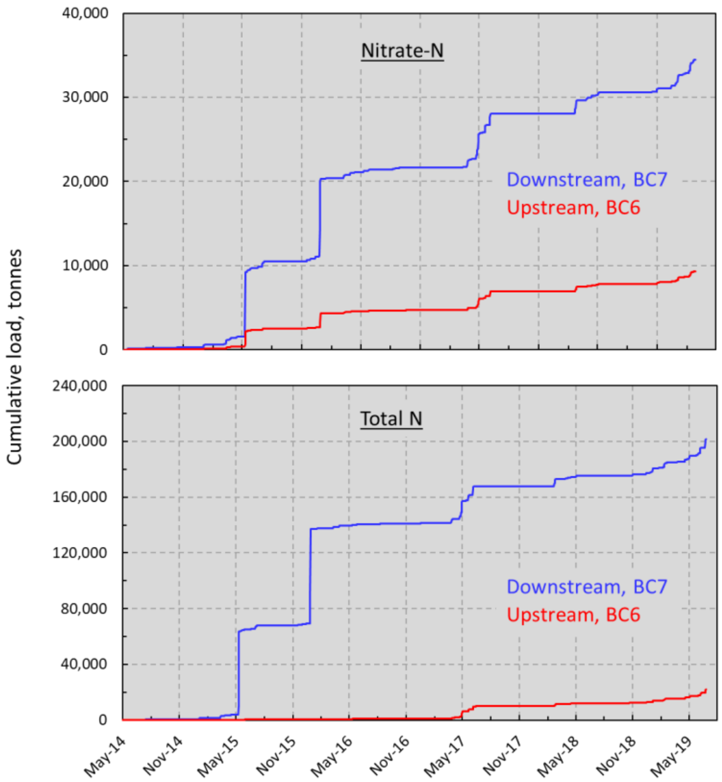

Figure S 11. Cumulative nitrate-N and total N load up (BC6) and downstream (BC7) of the C&H Farm on Big Creek with extreme May and December 2015 storms included.

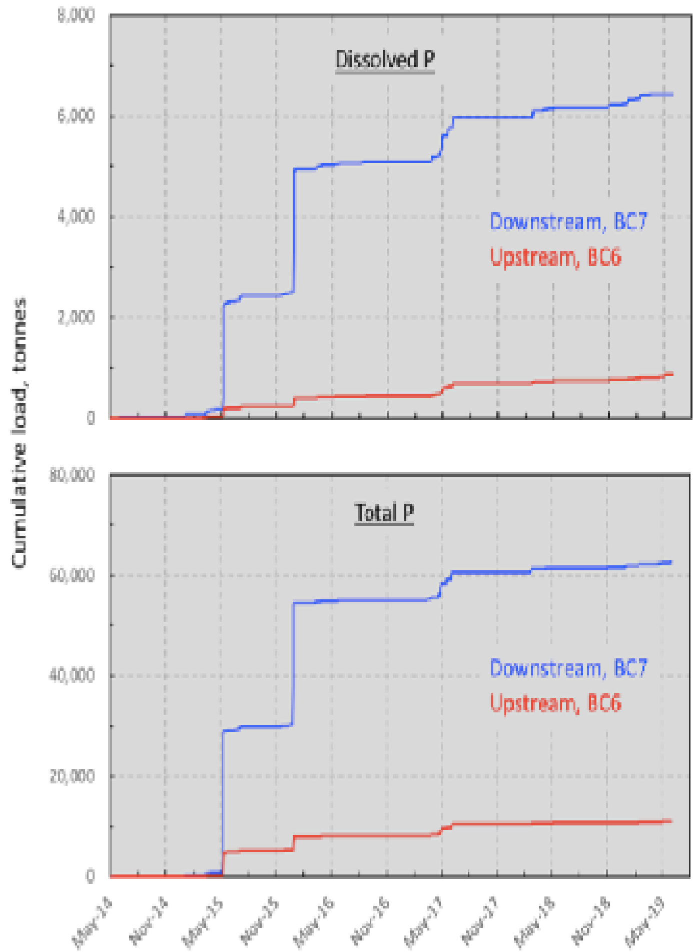

Figure S 10. Cumulative dissolved and total P load up (BC6) and downstream (BC7) of the C&H Farm on Big Creek with extreme May and December 2015 storms included.

However, after completing the expert review, and after posting the final report, BCRET was alerted to errors, most notably in Chapter 7 and subsequently a revised version was uploaded with this message: "*A coding error in Loadest was corrected and the resulting nutrient loads determined are provided in the section "Nutrient Loads in Big Creek Up and Downstream of C&H Farm 12-31-19 Revised" of the Final Report."* The revised charts now appear as shown below. {6}

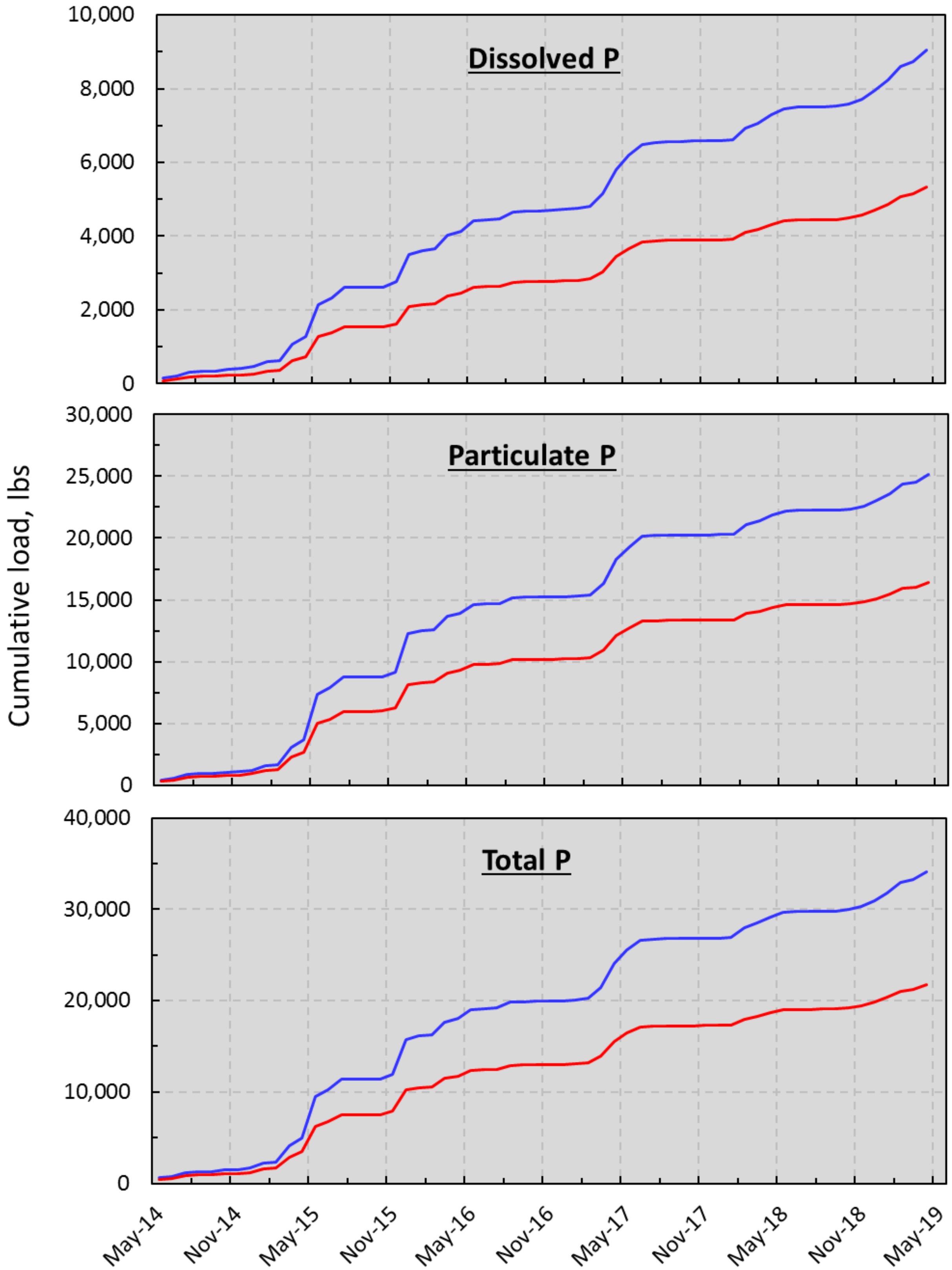

Figure S 6. Cumulative dissolved and total P load up- (BC6) and down-stream (BC7) of the C&H Farm on Big Creek.

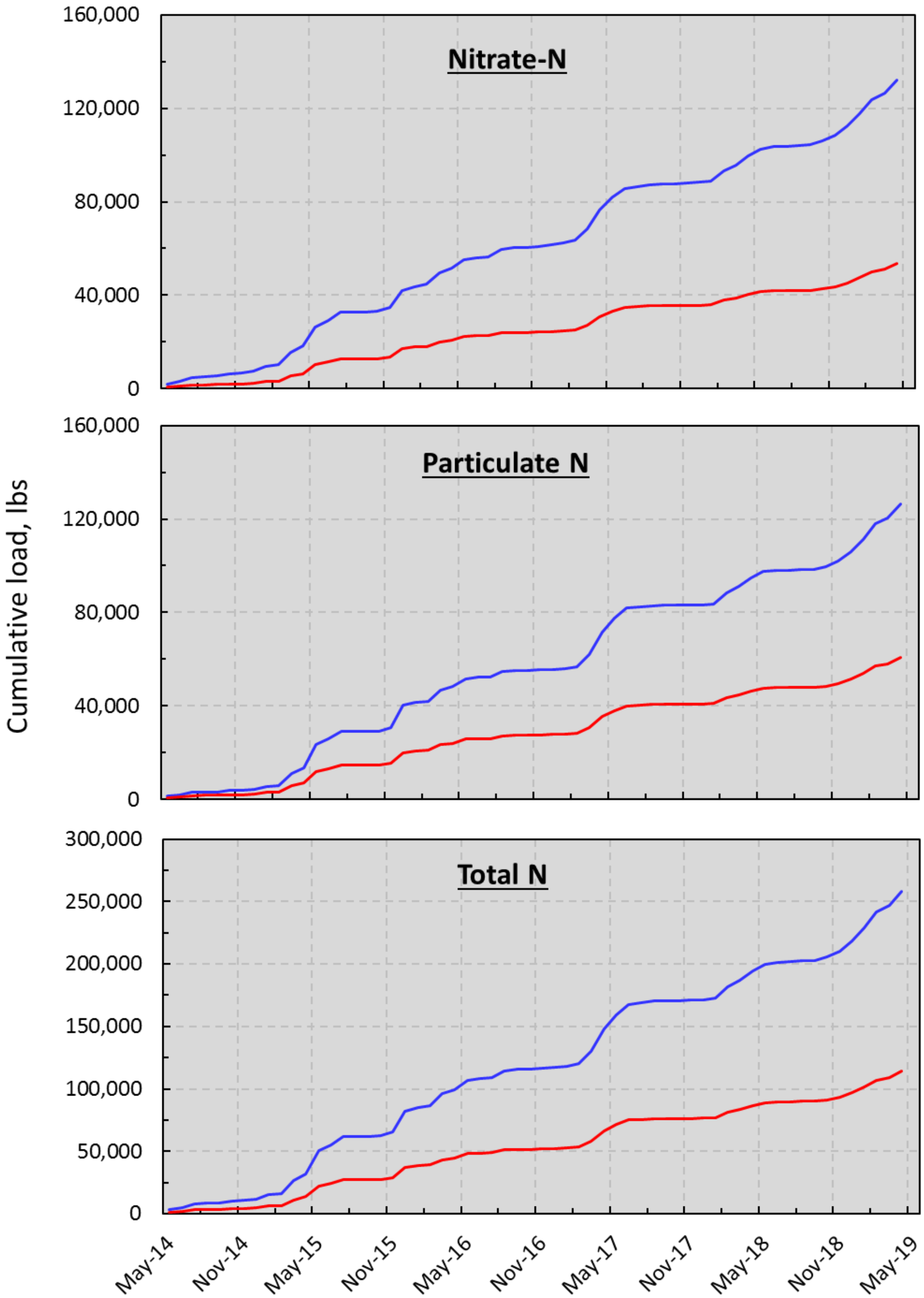

Figure S 7. Cumulative nitrate-N and total N load up- (BC6) and down-stream (BC7) of the C&H Farm on Big Creek.

The errors were said to be due to "accounting" and "coding" problems and, while there was little effort to interpret the results, even the revised charts reveal 2 important facts:

1. At the beginning of the testing period, in May, 2014, there was little difference between upstream and downstream levels of nitrate and phosphorus with very low levels of both nutrients detected. May, 2014 correlates with the beginning of field application of swine wastes by C&H.
2. 5 years later, at the end of the testing period in May, 2019, there was a significant upstream vs downstream difference, *with approximately 6 tons more Total P loading and 75 tons more Total N downstream than upstream*.

Even after correction, this data indicates that C&H is contributing substantially to the cumulative N and P loading in Big Creek.

5. Impact seen at sites adjacent to production facility and holding ponds BCRET acknowledges that measurements in the House Well suggest contamination.

> ***"There was a statistically significant (probability <0.0001) increase in nitrate-N concentrations in well samples … over the monitoring period (April 2014 to June 2019) …"***

BCRET acknowledges that measurements in the ephemeral stream suggest contamination.

> ***"There was a statistically significant (probability <0.0001) increase in nitrate-N concentrations in ephemeral stream … over the monitoring period (April 2014 to June 2019) …" {9}***

6. Clay holding pond leakage - Engineering estimates

Construction of clay ponds assume leakage. The original engineer (Nathan Pesta) conducted tests and calculations to estimate the leakage.

Pond 1 calculated seepage rate per acre: 3448 x .4788 acres = 1651 gallons leaked per day

Pond 2 calculated seepage rate per acre: 4060 x .8095 acres = 3286 gallons leaked per day Total seepage for 1.288 acres = <u>4,938 gallons per day.</u>

7. Runoff

BCRET acknowledges runoff risk of P and N but notes that, without baseline information, increases during the study cannot be known. This deficiency shows a significant flaw in the BCRET study.

"Grazing, slurry, and fertilizer management of Fields 1, 5a, and 12 over the 5 years of monitoring, may have resulted in an increase in the potential loss of P and N to Big Creek." {9}

The graphics referenced on pages 5 and 6 above indicate that N and P losses to Big Creek are in fact occurring.

8. Storm events and unavoidable runoff

BCRET notes that over 5 years, C&H experienced two major flooding events with significant run-off and that conservation practices are ineffective in preventing such runoff in the future.

"The two largest storms occurring during each of the 5-year monitoring accounted for 44, 49, 37, and 42% of the total 5-year load of dissolved P, total P, nitrate-N, and total N, respectively, and 43% of discharge measured at BC7. At the upstream site (BC6), these same storms comprised 45, 47, 42, and 44% of dissolved P, total P, nitrate-N, and total N load, respectively, and 43% of total discharge. During these large storm events, the monitored application fields BC5a and BC12 were mostly flooded as Big Creek breached its banks. Thus, the effectiveness of conservation practices, such as buffer strips or no-application zones for slurry would have little impact on the conservation of nutrients or limiting their movement to Big Creek, under such extreme flow events." {8}

9. Thin soils present subsurface contamination risk

BCRET tested three fields noting soil depths. Two fields had severe limitations (20" or less in depth) due to thin soils per USDA guidance and the third had moderate limitations (40" or less). All fields are underlain with epikarst. {12}

10. Karst significantly increases radius of contamination transport

BCRET acknowledges the entire area is underlain by karst:

"The Big Creek Watershed below the C&H Farm and application field locations, lie within a karst hydrologic system of great complexity exhibiting intimate connection of surface-water and groundwater regimes. These characteristics endow the hydrologic system as an important recreational resource locally and regionally, but also render the system vulnerable to contamination." {10}

BCRET references work by Kosič demonstrating complexity of karst.

"The dye-trace studies of Kosič (2019) and Kosič et al. (2015) demonstrate the high velocity with which groundwater flows can occur in the Boone karst setting of Big Creek Watershed (Table 1 and Figures 4, 5, and 6). It was evident from the eosin-dye injection that subsurface flows traversed surface drainage basins, with detects from the field adjacent to BC12 occurring in Left Fork sub watershed (Figure 6). The overall conclusions of the dye-trace studies of Kosič (2019) demonstrate the complexity of subsurface flows in the karst system in this area of the Boone formation. {11}

Shown below:

The impaired segments of the Buffalo River and Big Creek (draft 303d list), correlate closely with the dye trace conducted by Dr. Van Brahana. Dye injected at Mt Judea, in close vicinity to the C&H spreading fields, makes its way into the Buffalo, not just at the mouth of Big Creek, but a considerable distance both upstream and downstream as well. This shows the possibility that a single waste source of a large size in a karst location, such as C&H Hog Farms, could very well contribute to impaired waters throughout the area.

What is Legacy Phosphorous ?

Legacy Phosphorus is the phenomenon whereby excess phosphorus is stored in the soil profile and is released to waterbodies, including groundwater, slowly or intermittently over long periods of time.

Since 2013, raw swine sewage has been stored in two waste ponds, with 2.5 million gallons spread each year onto fields in the Buffalo National River watershed. Fields have received far more nutrients than vegetation potentially can absorb, and the soil has become heavily saturated with stored phosphorous. Now that the CAFO is closed and the spraying halted, this "legacy phosphorous" will continue to leach into the underlying karst, and will be washed into surface waters through rain events. It contaminates groundwater and resurfaces in seeps and springs that feed Big Creek and the Buffalo River (see map above). Too much phosphorous causes algal blooms. The dye trace studies cited in the BCRET Final Report show how far and how quickly water can travel underground. Assessing and cleaning up what is left behind in the C&H soils will take many years and require persistence and monitoring.

In a 2013 article co-authored by the principle investigator of BCRET, Dr. Andrew Sharpley, the seriousness of legacy phosphorous is stated:

". . . ***we face unprecedented challenges in meeting water quality targets, given that P legacies from past land management may continue to impair future water quality, over time scales of decades, and perhaps longer.***" {5}

REFERENCES

1. *BCRET Final Report, October 24, 2019, Executive Summary, pp. 6 & 7. C&H 2018 Hog Farm Annual Report.*

2. *BCRET Final Report, October 24, 2019. Chapter 7, pp. 30-31.*

3. *BCRET Final Report, October 24, 2019, Chapter 2, p.2.*

4. *Arkansas's Final/ Draft Impaired Waterbodies – 303(d) list, 2018.*

5. *Water Quality Remediation Faces Unprecedented Challenges from "Legacy Phosphorus", Helen P. Jarvie, Andrew N. Sharpley, Bryan Spears, Anthony R. Buda, Linda May, Peter J. A. Kleinman, Environmental Science & Technology, 2013, 47, 16, 8997 8998(Viewpoint)Publication Date (Web):August 9, 2013*

6. *BCRET Final Report, revised December 31, 2019, Chapter 7, pp. 29-31.*

7. *BCRET Final Report, October 24, 2019. Summary, p. 1.*

8. *BCRET Final Report, revised December 31, 2019, Chapter 7, Summary, p. 1.*

9. *BCRET Final Report, revised December 24, 2019, Executive Summary, p. 7.*

10. *BCRET Final Report, December 24, 2019, Chapter 2, p. 2.*

11. *BCRET Final Report, December 24, 2019 Chapter 2, p. 10.*
12. *BCRET Final Report, December 24, 2019, Executive Summary, p. 6*

Part 2: Expert Review of BCRET Quarterly and Final Reports

BRWA commissioned a review and expert opinion of the BCRET Quarterly Reports and October and December (revised) Final Reports by Dr. Mike Smolen, Ph.D, Environmental Sciences and Engineering, a highly qualified water quality and agricultural waste management specialist with Lithochemeia, LLC, Tulsa, Oklahoma. Attached to this submission are his "*Preliminary Report: Critique of the BCRET Project Evaluating the C&H Hog Farm Impact on Big Creek*", November 7, 2019, as well as his "*Comments on the BCRET Final Report*", dated January 17, 2020, from which we include excerpts below.

These expert opinions reveal to us that: 1) the BCRET 5-year study of C&H was largely inadequate, flawed and unreliable, with weak opinions and frequent obfuscations and is a poor basis upon which to judge the impact of C&H on ground and surface waters of the area, and 2) if, however, one filters through the errors and obfuscation and carefully considers what data *is* dependable, one sees a picture of irrefutable impact to the water quality of Big Creek. In spite of BCRET's implications that C&H has had no significant impact, it is clear from the data that the continued operation of C&H, compounded with the possibility of other similar facilities in the watershed, is a recipe for disaster with the Buffalo National River bearing the brunt. A halt to the issuance of permits for such facilities, ie: a permanent moratorium, is required and is justified by the near-miss of C&H.

We adopt and submit the entirety of both of these attached reports as comments of BRWA. Below are some excerpts.

Excerpts from Dr. Mike Smolen's Review of the BCRET Final Report, January 17, 2020

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 Monitoring

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.*

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*. 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.*

□□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 comparison of nutrient loading upstream and downstream of C&H, after revision] show that the C&H area contributes substantial amounts of nutrient to Big Creek.

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

Basis*. … there is 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 estimate 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.*

… 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.

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 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 December peak storm was not sampled at all.

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)*

BCRET further showed the stream loading of Nitrate-N at BC7 is almost double what is predicted based on the upstream water quality

*… 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

They [BCRET] make three arguments to reject the obvious conclusion that hog waste is entering shallow groundwater and contributing to streamflow between BC6 and BC7. [BCRET Executive Summary, items 11, 18 and 19]

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.*

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 [BCRET] 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.

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.

Conclusion 6. *The concentration of soil test phosphorus (STP) in the C&H waste disposal fields is increasing rapidly….The NMPs … 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.*

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).

If the cattle are in fact managed as indicated in the Nutrient Management Plan (NMP) submitted to ADEQ …, 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.*

Basis. *…the BCRET team avoided those fields most heavily used for waste disposal (Fields 7, 9, and 17).*

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.

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.

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

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.

… 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 water 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.

Excerpts of Dr. Mike Smolen's Preliminary Report, November 7, 2019

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.*

Conclusion

The statements above provide ample evidence that: 1) the C&H facility has had, and will likely continue to have, detrimental impacts on the water quality of Big Creek, a major tributary of the Buffalo National River; and 2) future facilities of a similar size and nature as C&H located in the Buffalo River watershed would only compound those impacts. This evidence is more than sufficient, and in fact is a warning sign, that the state should permanently cease the issuance, reissuance or modification of permits for such swine facilities in the watershed of the Buffalo National River. We urge the adoption of regulations 5.901 and 6.602 as drafted.

Thank you for the opportunity to submit these comments.

Gordon Watkins, President

Buffalo River Watershed Alliance

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

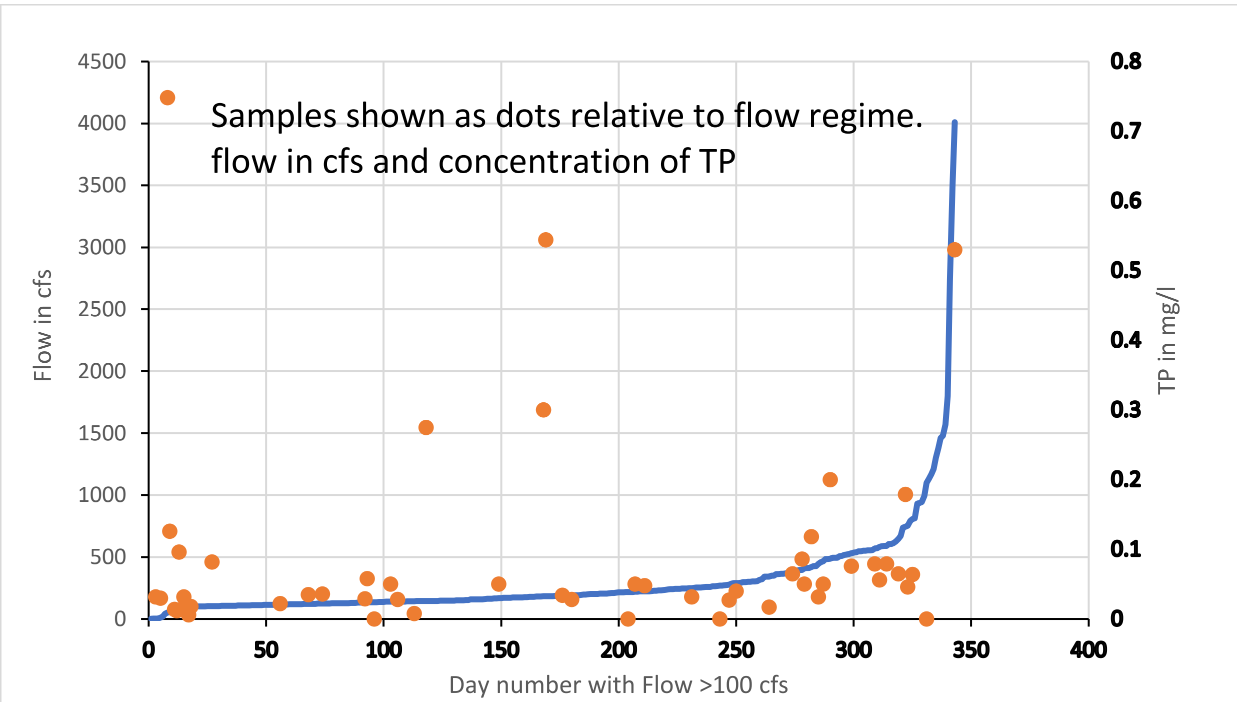

Figure 1. Analysis of sampling coverage of flows with mean daily discharge greater than 100 cfs. Shown is concentration of TP in samples from the downstream sampling site on Big Creek and the mean daily discharge at Mt Judea USGS gage.

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.

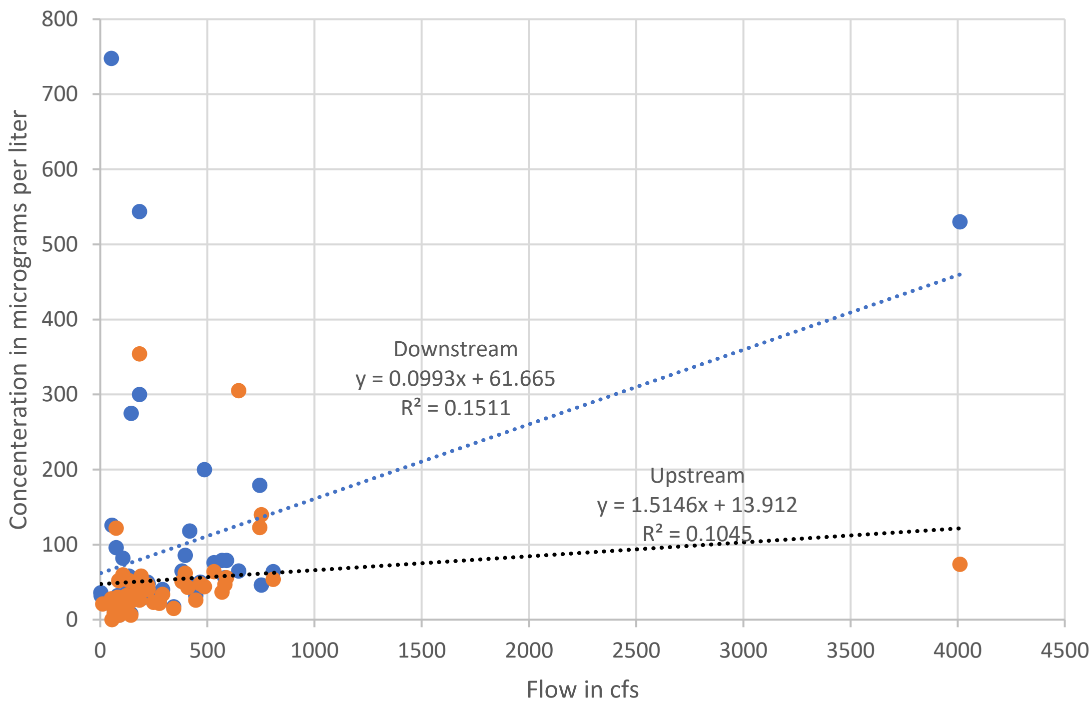

Figure 2 Concentration of TP upstream and downstream versus flow at Big Creek station. Concentration is in micrograms/l.

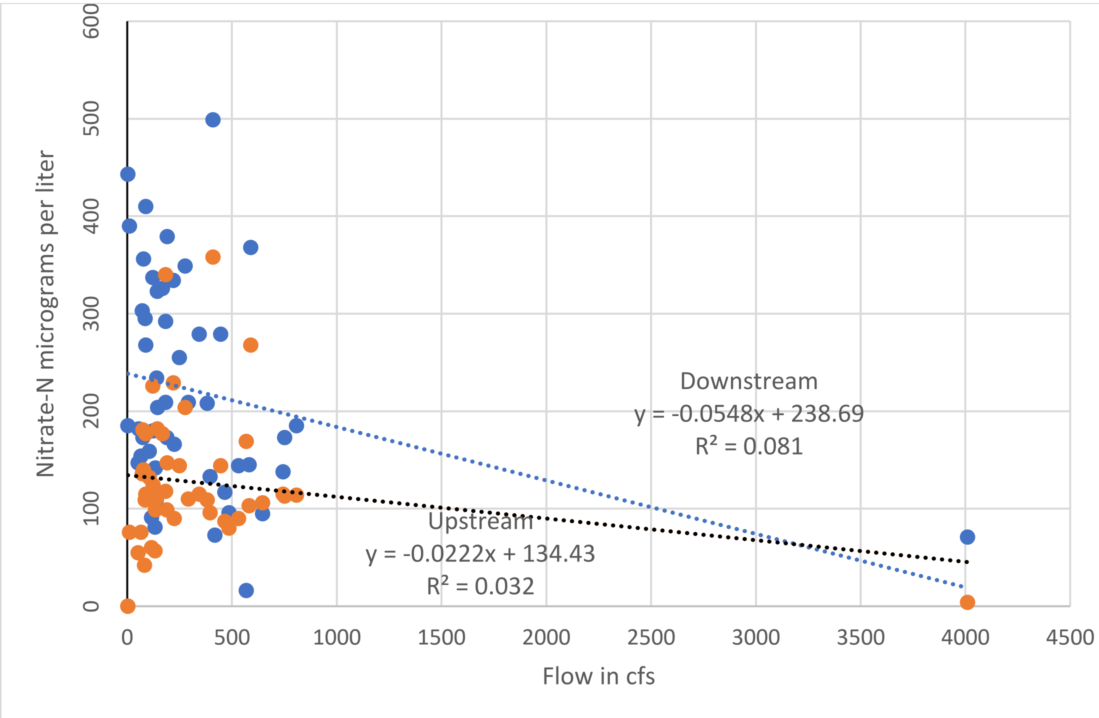

Figure 3. Regression of concentration of Nitrate-N versus Flow at upstream and downstream stations on Big Creek. Flow from Mt Judea USGS gage. Concentration is in micrograms/l.

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.

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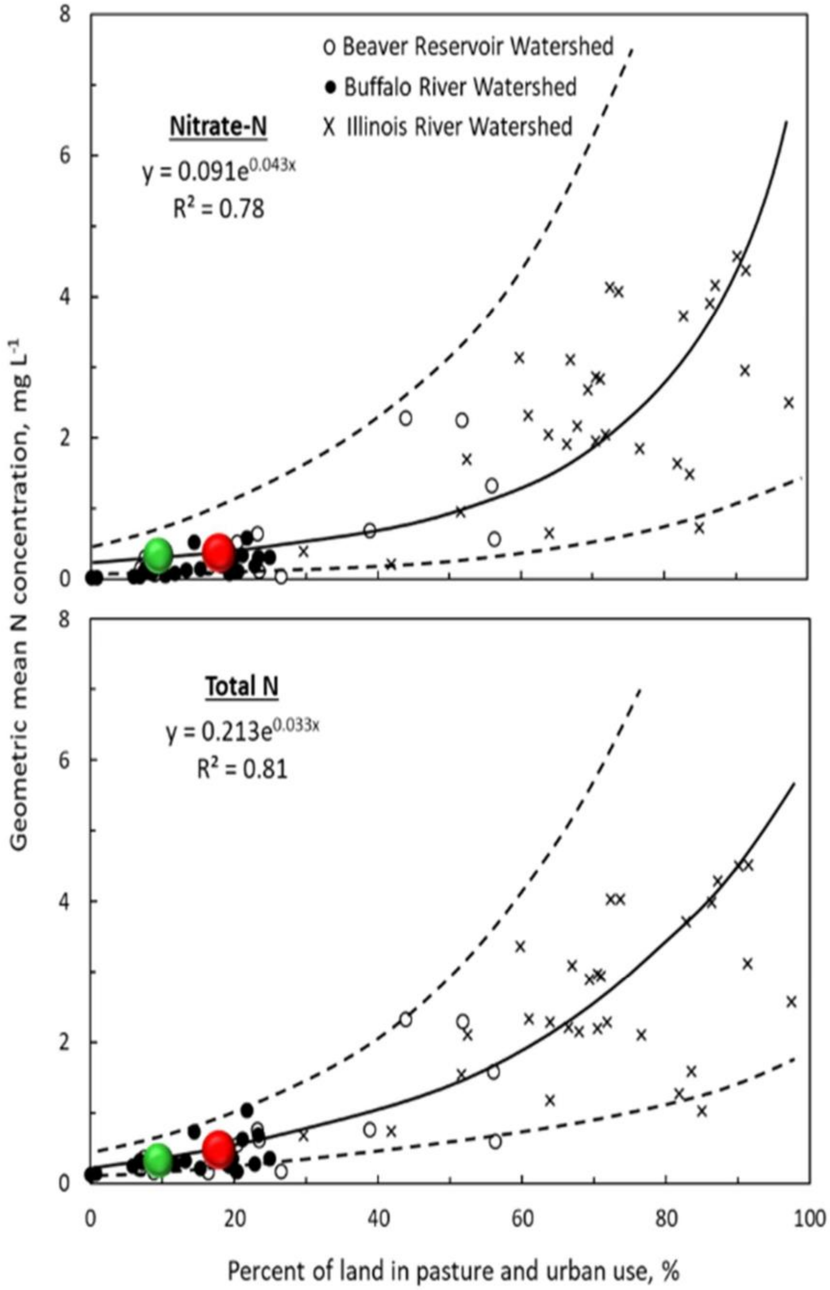

Figure 4. Extract from BCRET Quarterly Report April - June 2017, P 53 *[Figure 15. Relationship between land use and the geometric mean nitrate-N and total N concentrations in (mg L^{-1}) in the Buffalo River, Upper Illinois, and Upper White River Watersheds. Dashed lines represent the 95% confidence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

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Comments on the BCRET Final Report

M. D. Smolen, Ph.D.

January 20, 2020

LITHOCHIMEIA

Comments on the BCRET Final Report[1]

M. D. Smolen, Ph.D.

January 21, 2020

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.

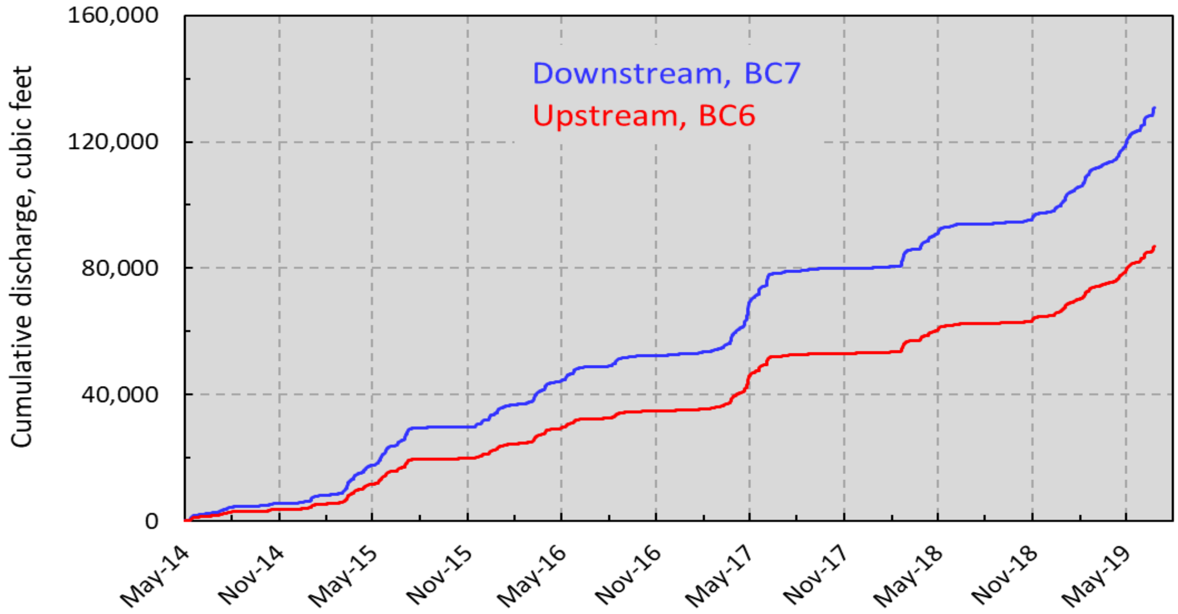

Figure 1. Cumulative discharge at BC6 and BC7 through the project period. (note values on y-axis are off by a factor of 1 million) (from BCRET Final Report)

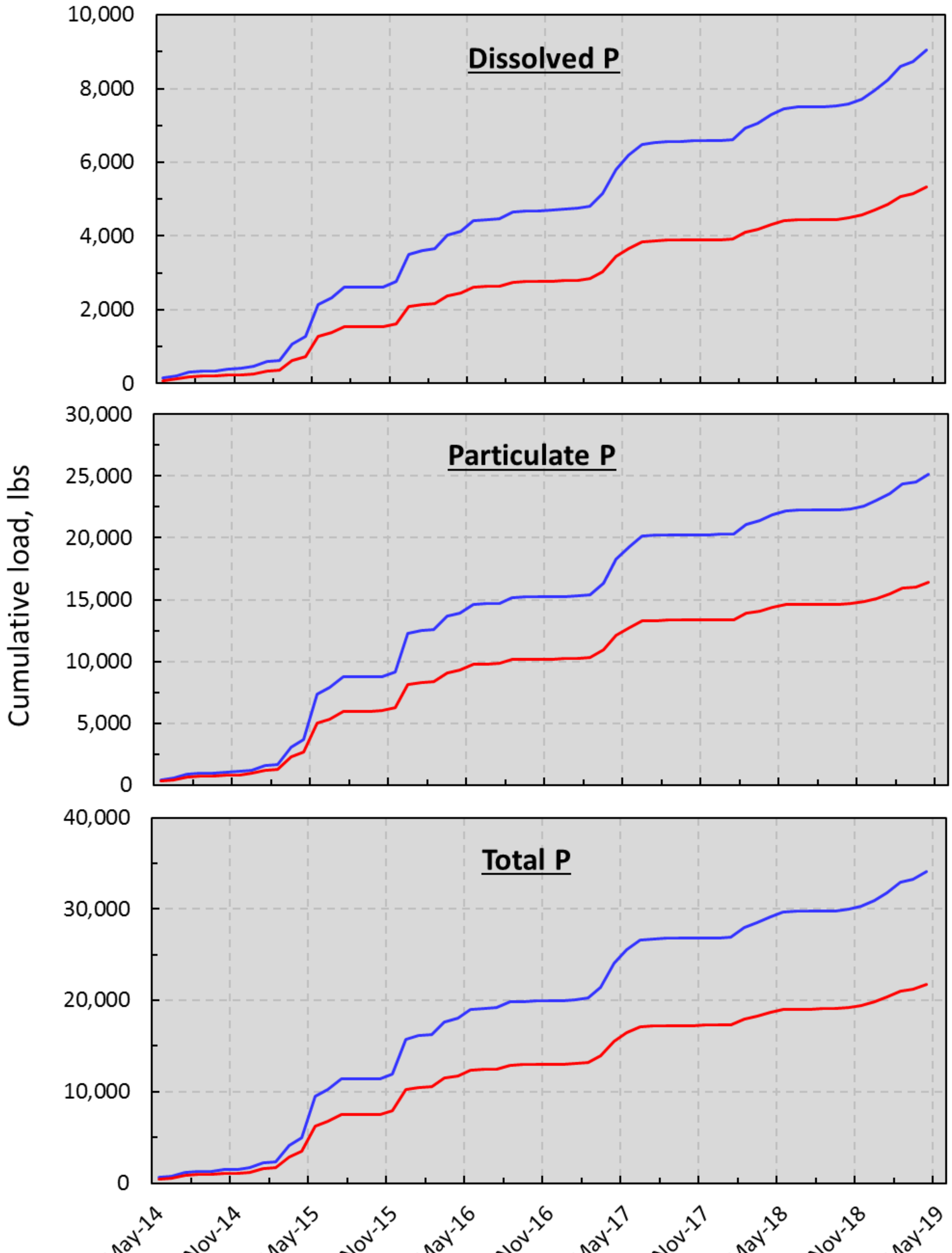

Figure 2. Cumulative loading of Phosphorus at BC6 and BC7. (from BCRET Final Report)

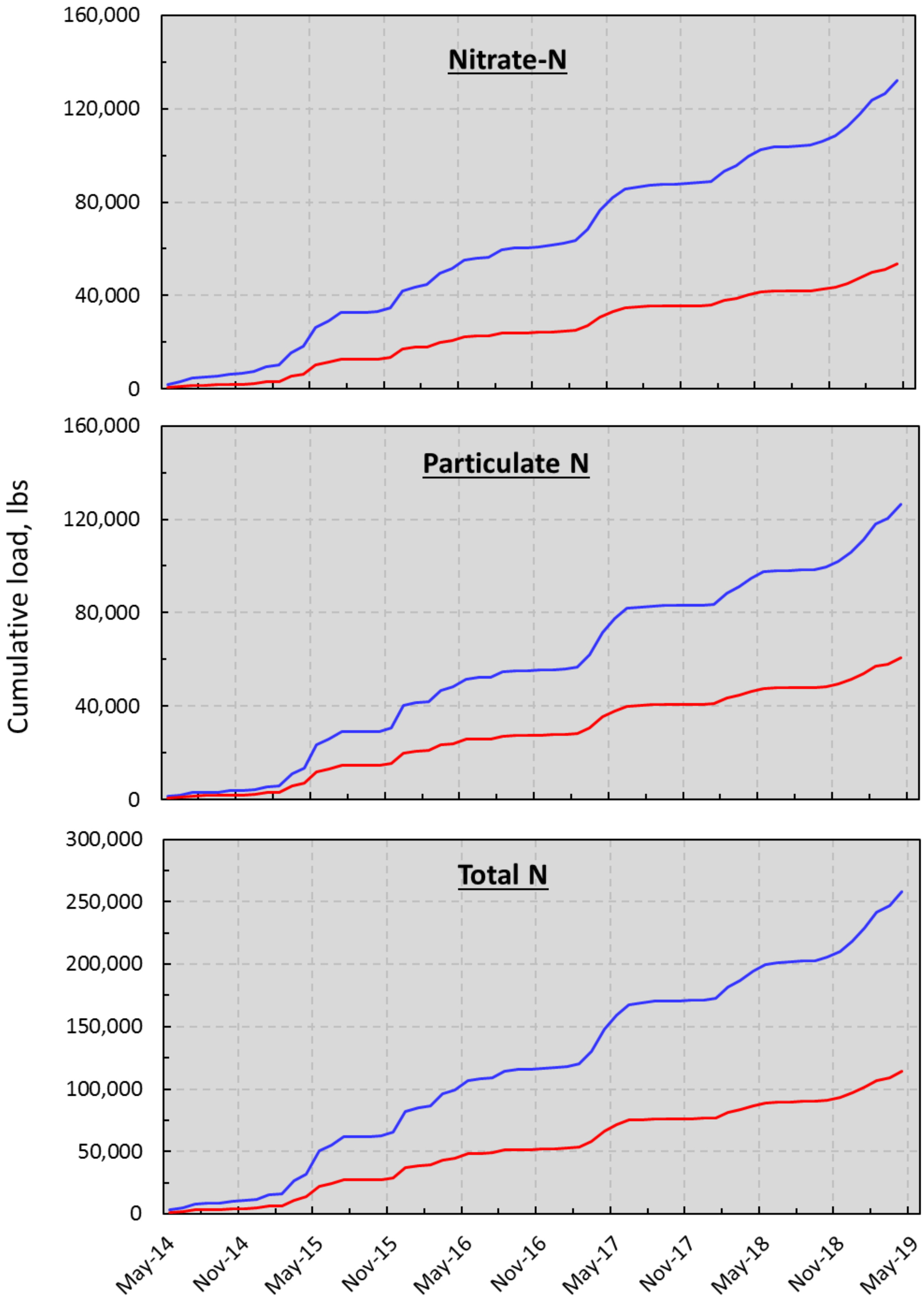

Figure 3. Cumulative load of Nitrogen at BC6 and BC7. (From BCRET Final Report)

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.

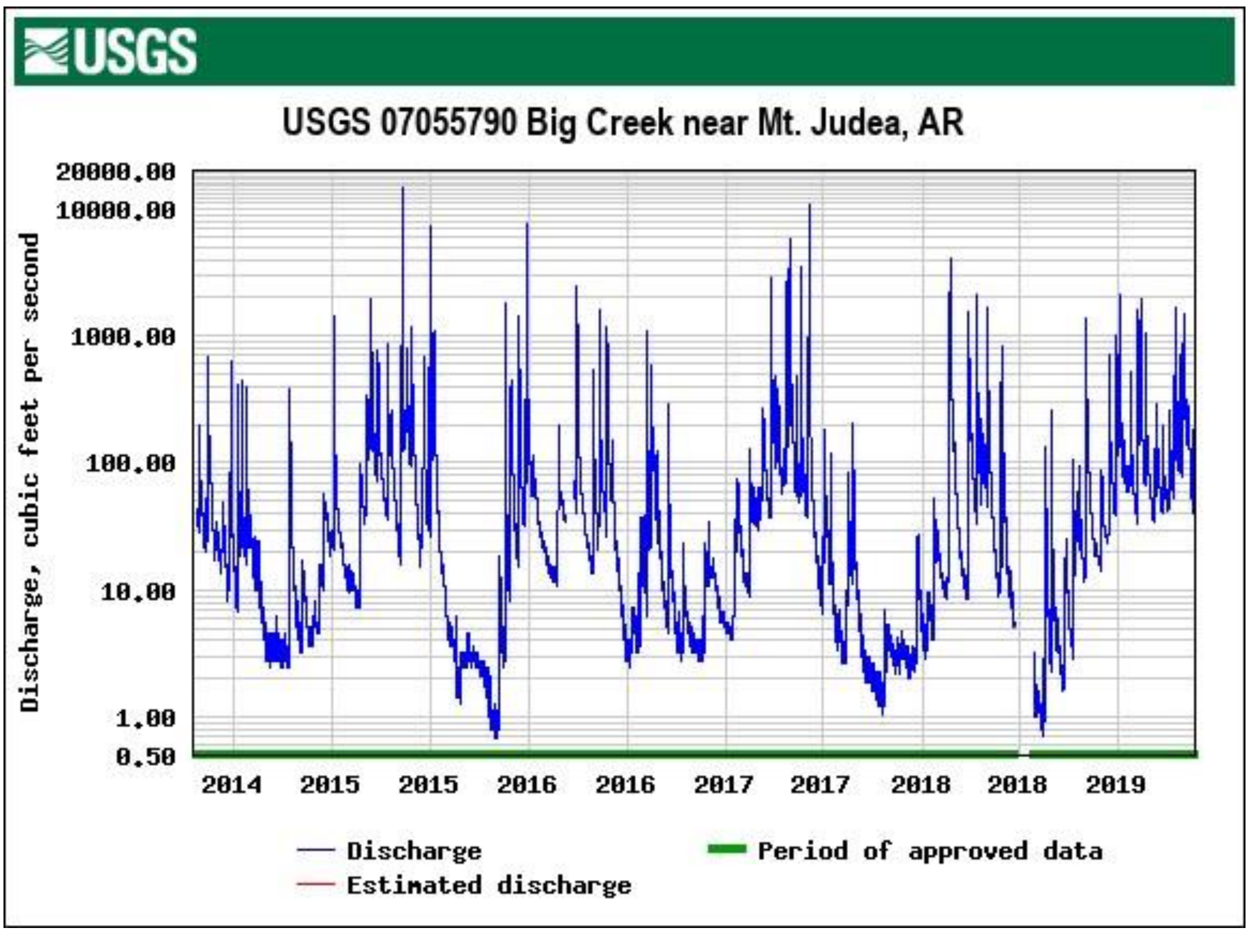

Figure 4. 15-minute discharge record from USGS at the Mt Judea gaging station.

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

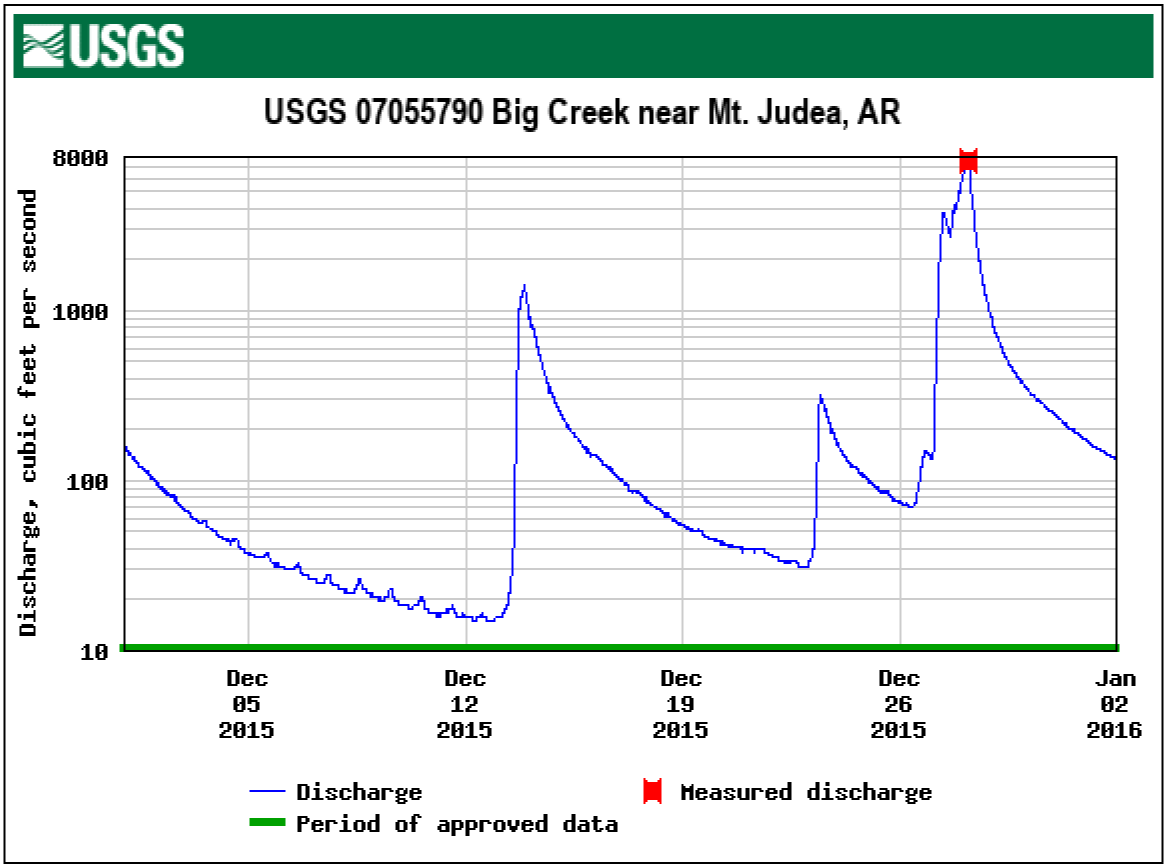

Figure 5. USGS hydrograph for December 2015 at station BC7.

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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ii

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