Comments supporting a Permanent Moratorium on Medium and large Hog CAFOs in the Buffalo River Watershed

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The Ozark Society, with 6 chapters and 1000 members, strongly endorses making the current temporary moratorium permanent. We fully agree with the DEQ moratorium proposal and published rationale. Specifically, we agree that engineering standards as applied to medium and large swine facilities in a karst area have not been adequate to protect Big Creek and the Buffalo River from nutrient pollutants, bacteria, and other swine-associated contaminants. Furthermore, possible remediation methods for waste treatment (e.g. sewage treatment, sludge removal, concrete holding tanks, phosphorus removal from the watershed, P application at agronomic rates) have not proven to be technologically or financially feasible. Therefore, permanent protection of the watershed is necessary. There is no need to repeat the C&H experience and a 6.2 million dollar buyout elsewhere in the watershed.

The Buffalo River is the first national river, offering clean water, wonderful vistas, whitewater and calm water, good fishing, and large, easily accessible, but still remote wilderness areas. The river provided recreation for 1.3 million visitors last year and is a major economic driver in the watershed. The Buffalo National River deserves permanent protection from medium and large swine CAFOs.

However, the Final Big Creek Research Extension Team (BCRET) Report deserves critical comment in order to put its conclusions and many pages of data interpretation into proper perspective. The Final BCRET report is highly technical and our response is also highly technical. A major problem is that the report makes few error estimates on the data input and therefore can't quantify the accuracy of its conclusions. Due to its lack of investigatory breadth, limited and flawed field sampling and data collection of swine waste-associated contaminants in surface water, inadequate characterization of the magnitude and timing of Big Creek surface water and stormwater runoff flows, most of the BCRET report results and conclusions cannot be confidently relied upon as a decision-making tool for assessing the impact of medium and large CAFOs on the Buffalo River watershed. Unfortunately, the authors provide no information or perspective regarding the uncertainty or variability of the study results, perhaps leading the uncritical reader to blithely accept the authors' conclusions. A good example is the chapter on surface runoff. Final Report inferences follow from column 6, table 7, page 15, the ratio of total phosphorus (TP) output and input (column 4 and 5) – neither of which is reliably estimated.

Another example of the inadequacy of the BCRET report is found in the recently re-drafted chapter 7 on nutrient loads. The apparent goal is to obtain estimates for yearly loads at BC6 and BC7 and thereby deduce the load generated in the farm stretch – a worthy goal of the investigation. But the model as presented is inscrutable (e.g. parameter values in the model are not given) and has the weakness of all models: it does not really represent the BCRET data set. As such, the results of the model are of unknown certainty. The OS presents a different method which gives similar but somewhat different estimates but includes an additional analysis of loading effects in the farm stretch

of Big Creek. Our modeling of this same nutrient release is more transparent, but there can be no certainty or reliance on model results without a meaningful error analysis.

Ozark Society technical comments will be in two parts:

I. Documenting differences in Big Creek stream nutrient and E. coli levels, above and below the farm - based on BCRET, USGS, and BNR data.

II. A detailed critique of several BCRET Final Report chapters.

Section I leads to three main conclusions.

Conclusion 1. The preponderance of evidence in the many charts and graphs shows that nutrient levels increase significantly in the stream and in the ground water along the farm between BC6 and BC7.

Conclusion 2: Unusually high and ever-increasing nitrate levels in the ephemeral stream, together with a similar trend in the house well, point directly to C&H Farm and its waste water lagoons as a primary source on nitrate pollution. The Final Report postulates some other source. But if there were another source, it was not functioning in 2014 when nitrate levels were between 0.4-0.5 mg/L, rather than 0.8-1.2 mg/L on 2019. The only identifiable source in this small watershed is the 38 acres of pasture, which, under normal pasture management would not have increasing nitrate discharges.

Conclusion 3: The nitrate and TP loads transported to Big Creek and generated in the farm stretch are far higher than would be found under the ambient conditions found upstream of the C&H Farm (BC6).

Caution to conclusion 2: The surface water samples from the ephemeral stream are taken from a culvert on the west side of City Road 41. According to StreamStats (United States Geological Survey, USGS), the watershed is 0.17 mi^2 (109 acres) with 35% pasture (38 acres). The amounts of nitrate applied to pasture from land-applying swine waste or other sources, are unknown.

StreamStats estimates that 28% of the surface water flow in the ephemeral stream is from ground water. The ephemeral stream watershed is a minor contributor (0.43%) to the overall flow contributed by the Big Creek watershed downstream of the farm at BC7. While the 2019 nitrate level in the ephemeral stream is 9-10 times the ambient level in Big Creek upstream of the farm (BC6), the ephemeral stream is unlikely to contribute more than 4.3% of the nitrate in Big Creek downstream of the farm at BC7. The larger flow of nitrate from C&H is likely to result from surface runoff or infiltration from swine waste applied to the spread fields.

Data analysis: A common assumption in stream flow analysis is that data has a log normal distribution, i.e. for a data set X, log(X) is normally distributed. This can be the basis for exponential curve fitting analysis in Excel. For lognormal distributions X, median(X) = geomean(X), so it is unnecessary to use the complicated geomean formula rather than the simple median. But the converse is not necessarily true, if median(X) = geomean(X) the distribution might not be lognormal. In the chapter, “Nutrient Concentrations in Big Creek Correlate to Regional Watershed Land Use,” the BCRET team uses the lognormal assumption, without justification, to generate exponential curve fitting when bilinear models might be more appropriate.

Geomeans are useful for analyzing data with extreme ranges. For instance, the range for E. coli in Big Creek is 0 to 15,000 colonies/100 mL. But for nutrient data, the use of geomeans can obscure meaningful differences.

Flow weighted means (lbs/sec) are used for computing the mass transport rate for varying flow and concentration regimes in streams.

Proportional Flow Assumption. The BCRET final report assumes, in the absence of more complete information, that Big Creek discharge is proportional to drainage area. Given this assumption, the watershed above BC6 is 66% of the watershed above BC7. And therefore, the discharge at BC6 is assumed to be 66% of the discharge as BC7. There is some support for this assumption (figure 1), but especially during low flow, it may be entirely wrong (figure 2). Nutrient pollutants in Big Creek may miss detection at Carver because there are alternative subsurface flow paths (karst) downstream of Carver to the Buffalo River. The same may be true between BC6 and BC7, but there is no way to investigate this without a gage on Big Creek at BC6.

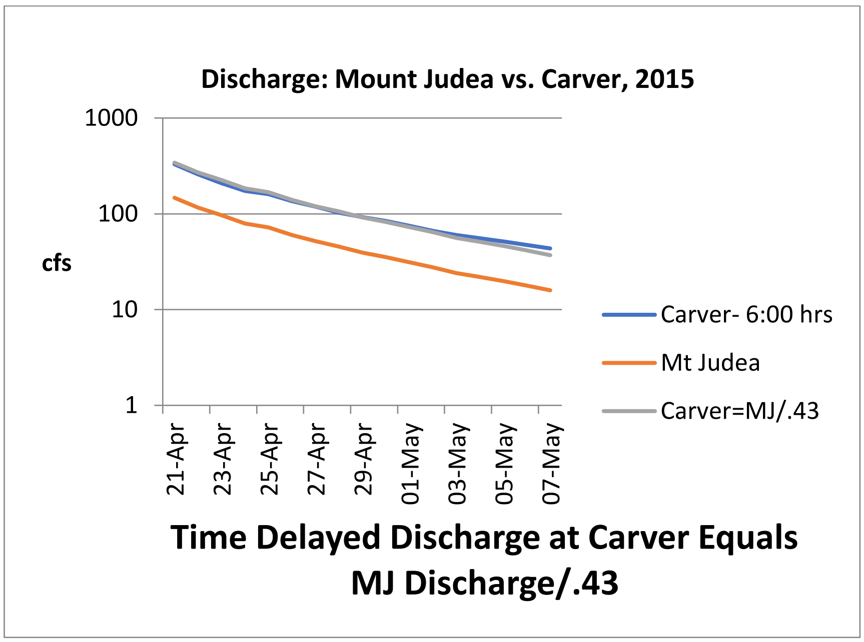


Figure 1. The Big Creek watershed above BC7 is 43% of the watershed above the Carver gage (functional between 2015-17). After allowing for a time delay of 6 hours between the two gages, the actual discharge at Carver (blue) equals discharge at BC7/.43. USGS data. In this case, discharge is proportional to area.

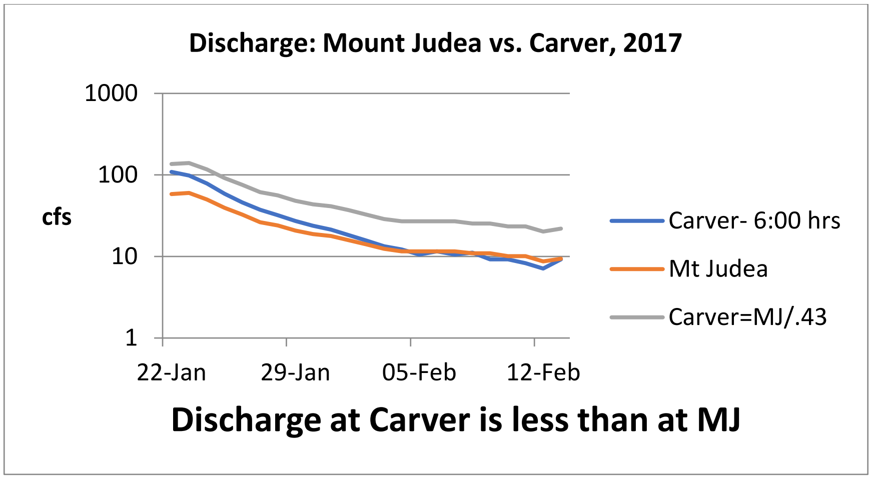


Figure 2. The Big Creek discharge at Carver (blue) is ***less than*** *at BC7 (orange) despite having a watershed that is more than twice as large. USGS data. Especially during low flow conditions discharge is not even close to being proportional to area.*

During low flow conditions, ground water, rather than runoff, is the predominant flow from Big Creek. Figure 3 illustrates that ground water at the Mount Judea gage on Big Creek below the farm (orange dots) has far higher nitrate concentrations than groundwater at Carver (blue dots). So, a plausible explanation for the difference in nitrate concentrations in Big Creek at Mt. Judea and the downstream station in the Buffalo River at Carver is that Big Creek is a losing stream, i.e., during periods of low flow (such as the summer), flow in Big Creek results predominantly from groundwater that appears in Big Creek as surface water. Nutrient concentrations flowing from Big Creek into the Buffalo River are diluted by the time they are measured at Carver and measurements of nutrients at Carver do not necessarily capture all the flow from the Big Creek watershed to the Buffalo River (i.e., subsurface flow of nutrients from Big Creek to a location downstream of Carver). Thus, measurement of nutrient concentrations at Carver is not a useful indicator of nutrient loading from C&H Farm and Big Creek.

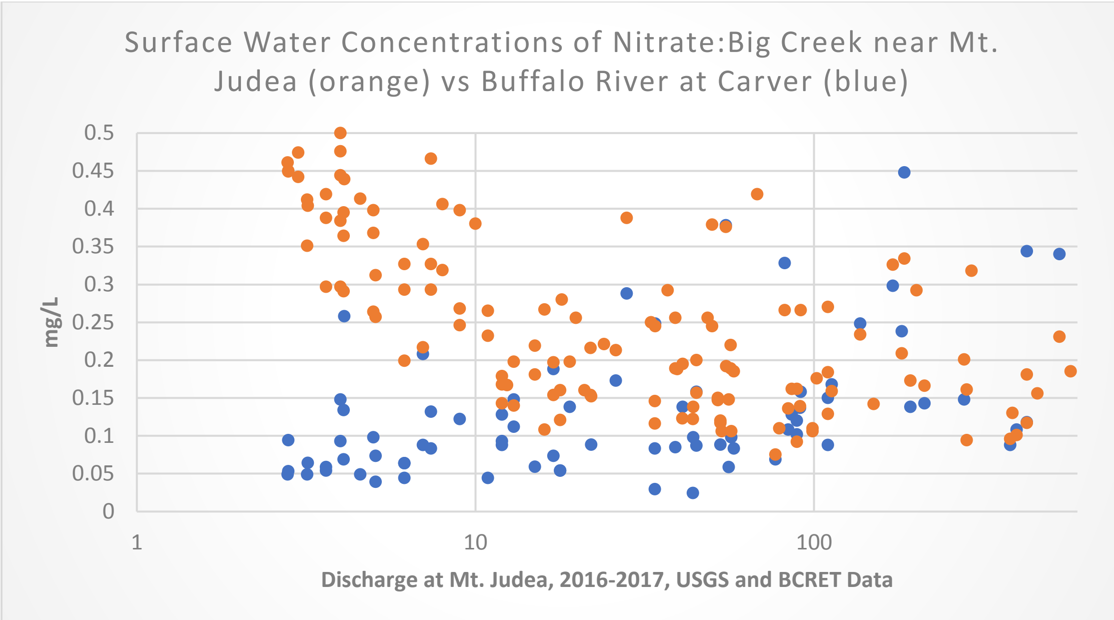


Figure 3. The Carver gage on Big Creek is about 6 miles downstream from Mt. Judea. The low flow nitrate response at Carver is completely different from at Mt. Judea (BC7). On Big Creek near Mt. Judea, groundwater is the predominant source of surface water flow during low flow (< 15 cfs). It also implies lower groundwater nitrate pollution at Carver than below the farm. Furthermore, at low flows the high nitrate concentrations in Big Creek have other paths to the Buffalo River (see figure 2 above). Dilution and denitrification may of groundwater daylighting as surface water may also occur between Mt. Judea and Carver.

Documenting Changes in Big Creek Stream Parameters, 5/1/2014 – 6/25/2019

NITRATE: The Ozark Society generally agrees with the Final Report that nitrate concentrations in Big Creek are higher downstream of C&H Farm than upstream of the farm. The applications of nitrate on the fields has been steady for more than 5 years. Since nitrate is water soluble there is little holdover in the soil from year-to-year. As expected, concentrations show seasonal trends but no long-term time trend of increasing or decreasing nitrate concentration. But nitrate levels in Big Creek below the farm are significantly higher below the farm than above (figure 4).

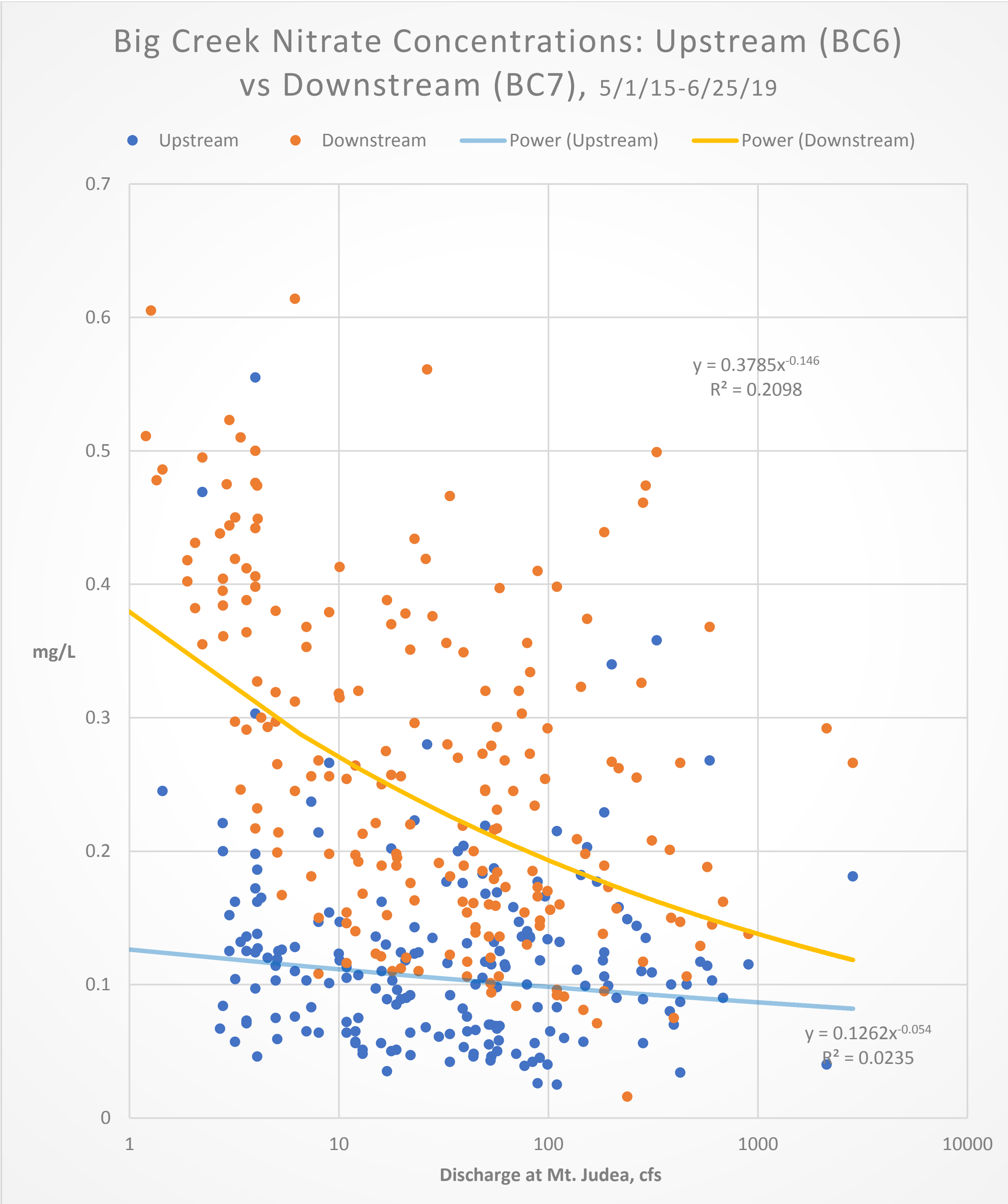


Figure 4. The nitrate concentrations downstream from the farm (orange) are significantly higher than upstream from the farm (blue) ($p < 10^{-10}$, paired difference test). The difference is greatest, a factor of 4 or more when groundwater flow dominates, discharge < 10 cfs. The groundwater influence is washed out during high flows.

In low flows ground water is the predominant source of surface water flow. Since there is a marked increase in concentration downstream on Big Creek during low flows but not upstream on Big Creek, this suggests elevated nitrate levels in surface water the source of which is ground water downstream of C&H Farm. Figures 3 and 4 illustrate that significantly elevated nitrate levels in surface water resulting from ground water flow are contributed by C&H Farm operations.

Numeric Comparisons, Nitrate

	Mean	Median	Geomean	Flow Weighted Mean	Average Yearly Load*
Upstream	0.123 mg/L	0.110	0.105	0.120	4.35 tons
Downstream	0.266	0.252	0.235	0.227	12.5 tons
% Increase	116%	129%	124%	89%	

Note: The load estimates are: the flow weighted mean times the average yearly discharge.

Total Nitrogen – TN: TKN (Total Kjeldahl nitrogen) is the sum of organic nitrogen, ammonia and ammonium. TN = nitrate + TKN. In Big Creek, nitrate is about 69% of TN, but varies in response to many factors including discharge and farming practices. The test for nitrate concentrations can be automated and is inexpensive, but not so for TKN.

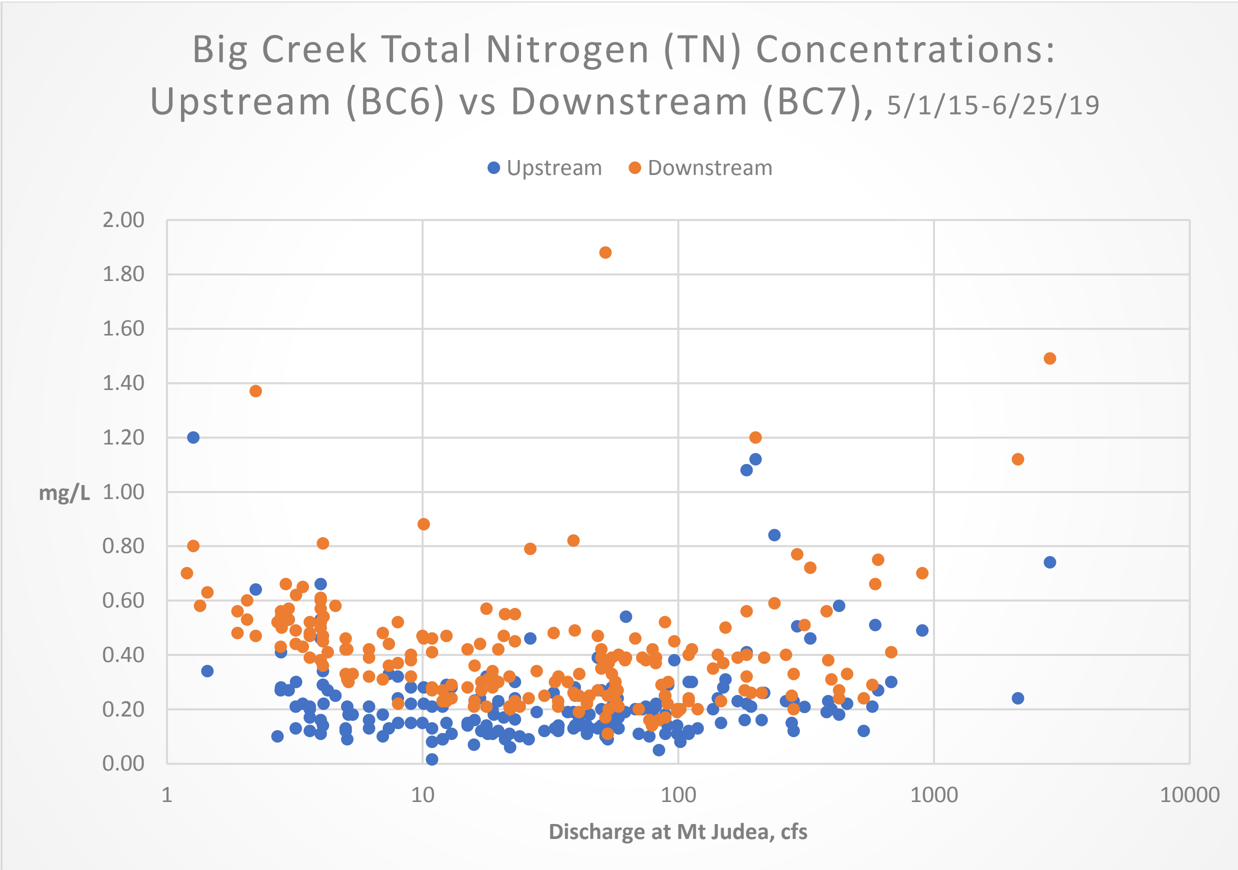


Figure 5: The downstream TN concentrations (orange) are significantly higher than upstream (blue) TN concentrations ($p < 10^{-10}$, paired difference test). As with nitrate there is a pronounced low flow increase downstream. Although nitrate was negatively correlated with flow, that is not the case with TN because the nitrate:TN ratio is discharge dependent, perhaps reflecting seasonal patterns and agricultural uses.

Numeric Comparisons, TN

	Mean	Median	Geomean	Flow Weighted Mean	Average Yearly Load
Upstream	0.232 mg/L	0.190	0.195	0.338	12.24 tons
Downstream	0.413	0.380	0.372	0.628	34.46 tons
% Increase	78%	100%	91%	86%	

Dissolved Phosphorus - dP

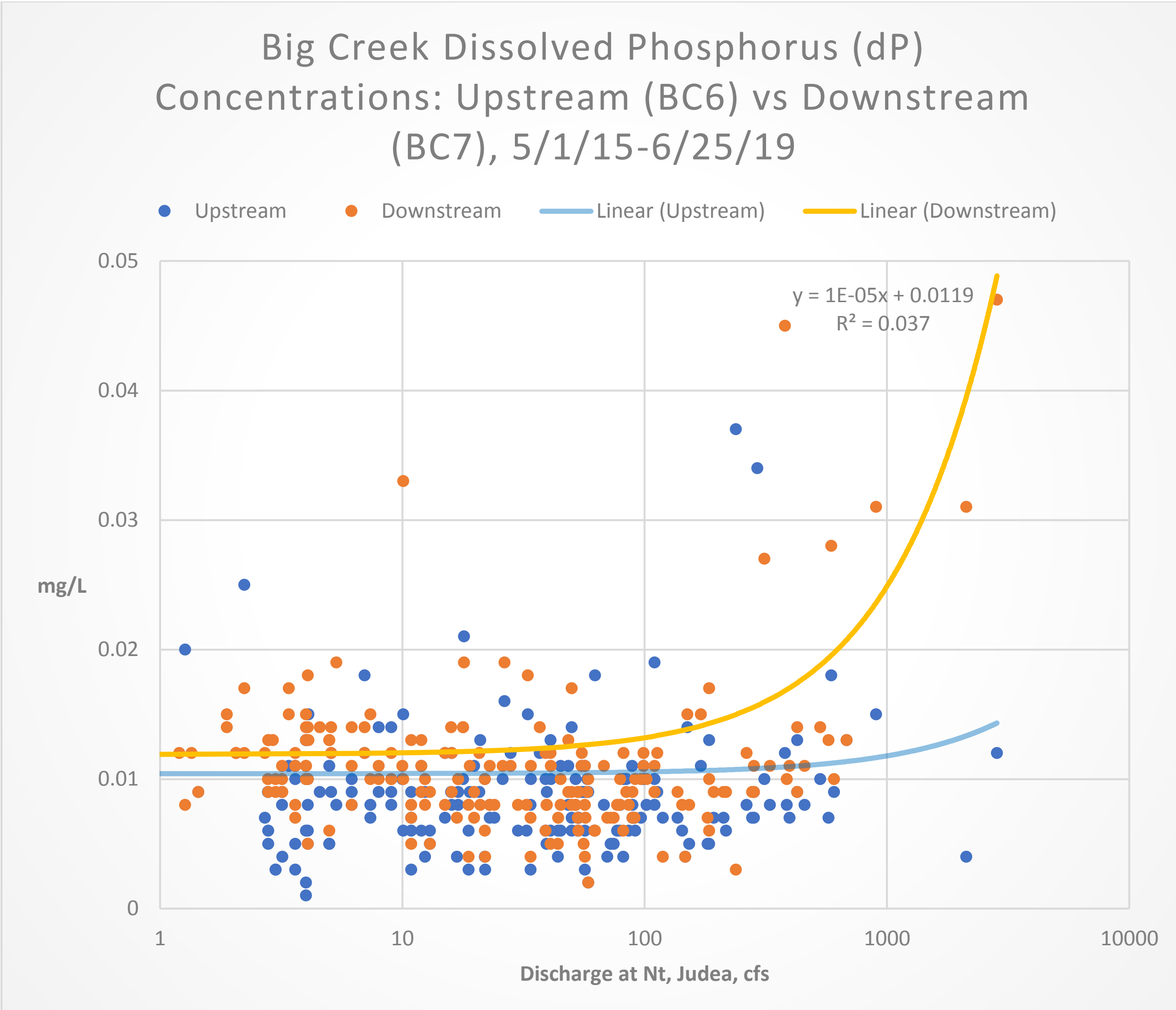


Figure 6. For discharge less than 100 cfs, downstream concentrations (orange) are flat and about the same as upstream (blue), (p =0.026), paired difference test), but during high flows downstream dP is typically much higher (not all downstream outliers are shown). As a result, load estimates downstream are almost triple the upstream load. The data reporting and confidence in the resulting analysis is made more difficult because some values are below the analytical reporting limit for dP.

Numeric Comparisons, dP

	Mean	Median	Geomean	Flow Weighted Mean	Average Yearly Load
Upstream	0.011 mg/L	0.008	0.008	0.0115	0.42 tons
Downstream	0.014	0.010	0.011	0.0226	1.24 tons
% Increase	27%	25%	38%	97%	

Total Phosphorus – TP

Total phosphorus is the sum of all forms of phosphorus in water: TP = dP + particulate phosphorus. In streams like Big Creek and the Buffalo River, TP is the limiting nutrient for plant growth, including algae.

Accurate estimates of TP loading require storm water flow analysis - 93% of the TP load at BC7 occurred on the 17% of the BCRET sampling dates when discharge was greater than 120 cfs (median discharge = 26.2 cfs).

But whereas dP, orthophosphate, is readily measured using a blue dye, the test for TP is expensive laboratory work. For this reason, few studies, including the BCRET Final Report, generate detailed TP profiles during storm events. This is a problem for two chapters in the Final BCRET Report: "Nutrient Loads in Big Creek Up and Down Stream of C&H Farm," and "Nutrient Creek correlate to Regional Watershed Use," which relied on dated and infrequent base flow sampling.

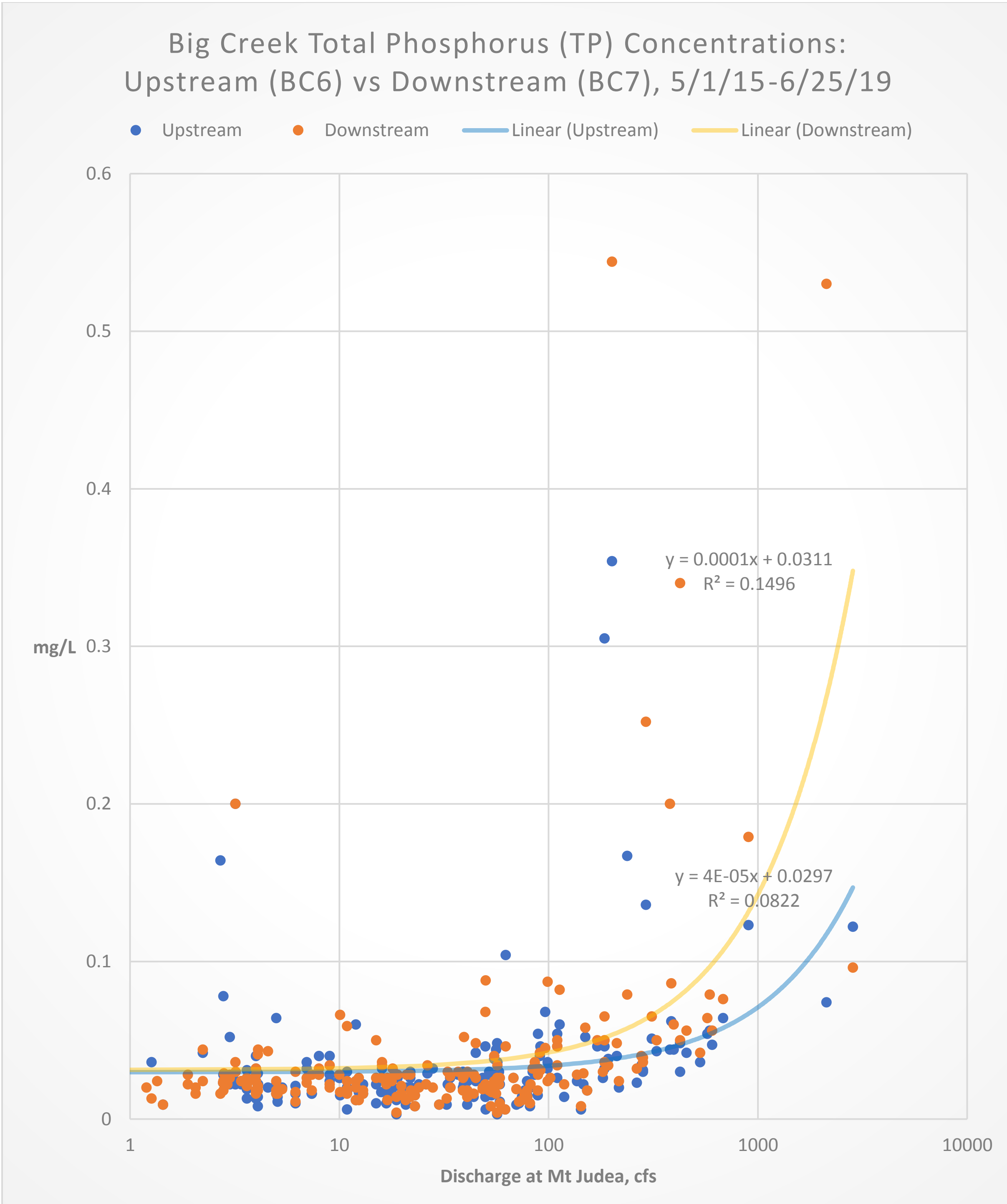


Figure 7. Visually, the TP concentrations downstream from the farm (orange) are essentially the same as above the farm (blue) for discharge < 80 cfs. But above 100cfs, the storm flow levels are significantly higher downstream. This high discharge skew is confirmed in Table 1 by noting 1. the equal medians upstream and downstream, 2. the means are much higher than the medians, 3. the very large difference in load and 4. the barely sufficient p-value for difference (p = 0.036, paired t-test).

Numeric Comparisons, TP

	Mean	Median	Geomean	Flow Weighted Mean	Average Yearly Load
Upstream	0.037 mg/L	0.024	0.026	0.064 (0.056)	2.32 (2.03) tons
Downstream	0.044	0.024	0.026	0.123 (0.078)	6.75 (4.28) tons
% Increase	19%	0%	0%	92% (22%)	

Table 1.

The TP anomaly: The sporadic nature of storm events makes it difficult to determine whether there has been a change in TP over time. But the BCRET Final Report, #17 on Page 8, used weighted regressions on time, discharge, and season (WRTDS) to deduce reductions in TP over time. Indeed, using yearly TP medians to represent base flow, there seems to have been a decrease from water year 2015 to 2018 (figure 8). But this pattern does not hold for dP (figure 9). What could explain a decrease in particulate P = TP – dP over time but not dP? Apart from changes in stream sediment and so forth, there may be issues with surface water sampling technique and/or laboratory analyses. For the first 171 data points in the BCRET report (9/12/13- 8/31/17) there were no instances of dP = TP (i.e. technically implying particulate P = 0). But for the last 79 data (9/6/17-6/27/19), 11 of 71 values gave dP = TP. The particulate P was 61% of TP in the first period but only 43% in the latter.

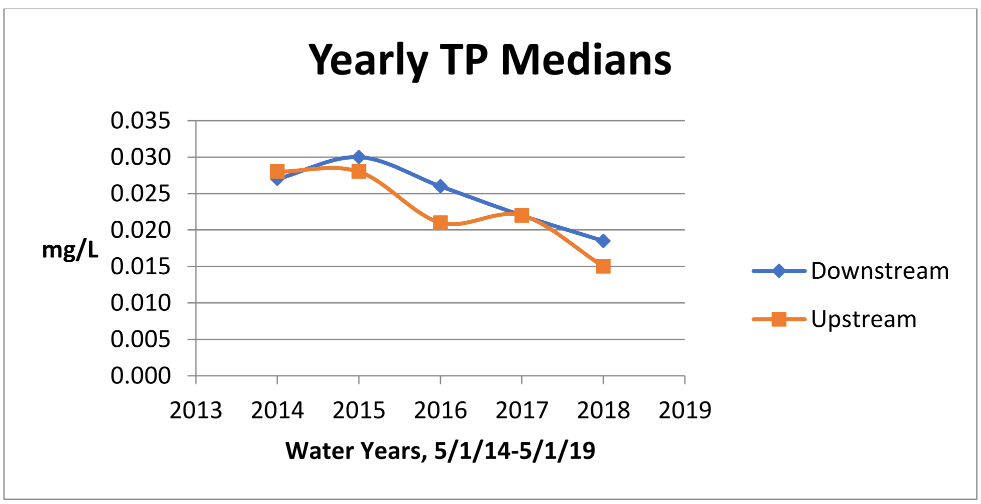


Figure 8. TP medians (base flow) decrease over time.

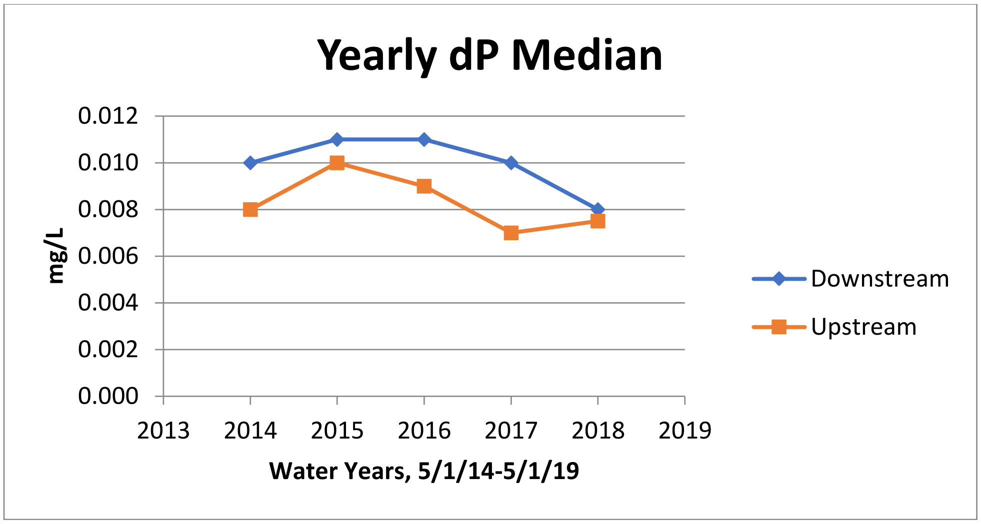


Figure 9.

The House Well:

The C&H "house well" is a deep well that serves as a water source for the farm. It is close to the swine waste holding ponds and barns. The graph below shows a steady increase in nitrate levels since 5/1/2014 indicating a nearby source of nitrate leaking into the well – perhaps the lagoons leak, there is reoccurring surface spillage that eventually permeates the immediate area or there is some other explanation. In general, liquid waste lagoons have been found to leave a plume of groundwater contamination under the ponds after they are closed. Such a plume may be causing the increase in the well and ephemeral stream.

The house well nitrate levels (deep groundwater) in 2019 are larger than groundwater near Big Creek, as inferred from low flow conditions.

	House Well	Downstream	Upstream	
		BC7	BC6	Carver
Nitrate:	0.8 mg/L	0.4-0.5 mg/L	0.1-0.2 mg/L	0.05-0.15 mg/L

TP levels in the house well are low, mean = 0.015 mg/L, with little or no time variation, and minimal standard deviation of 0.0085 mg/L with few outliers. This reflects the characteristic lack of subsurface mobility of TP and the depth of the water intake at some 250 feet.

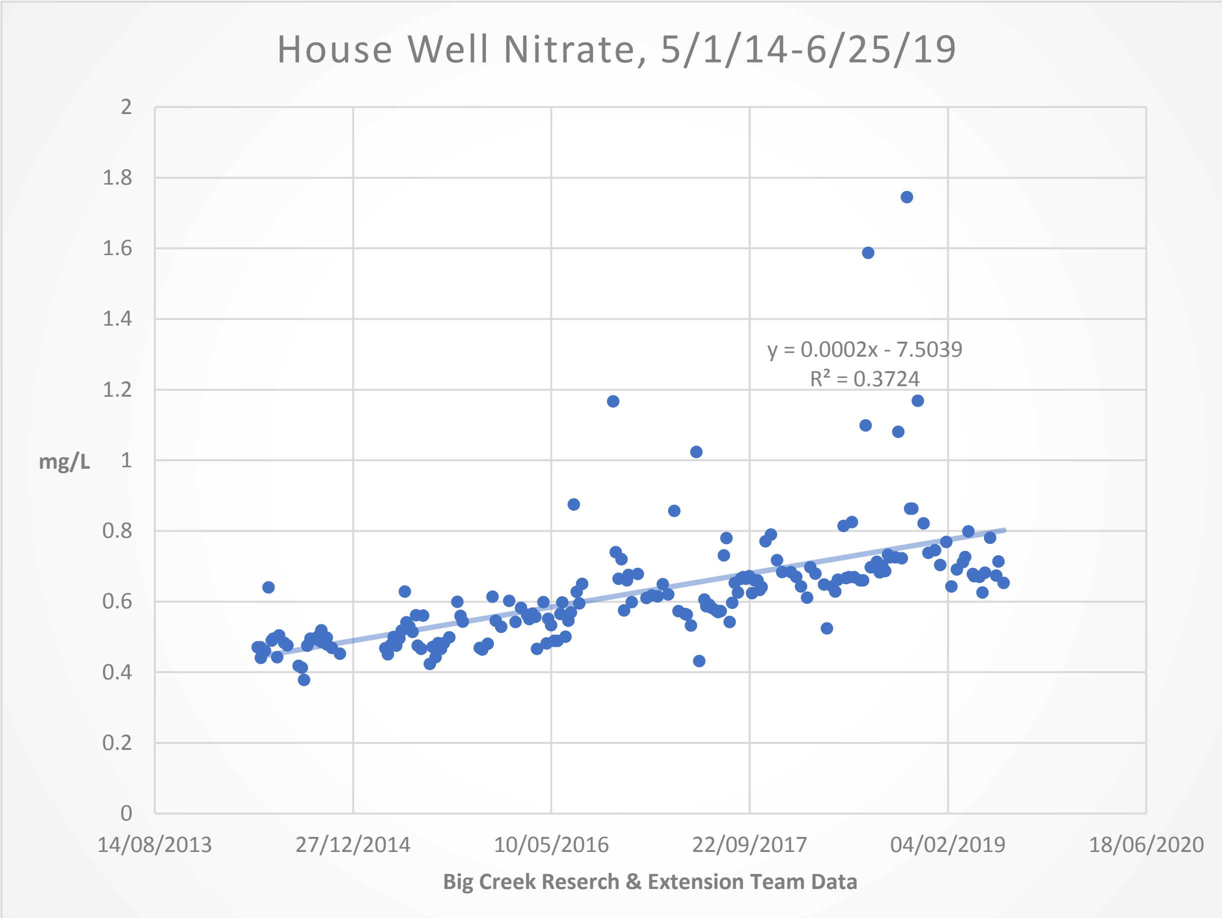


Figure 10. The well is some 500 ft deep and water is drawn from about half way down. The steady increase in nitrate levels implies a long-term source, perhaps a plume from the lagoons or ephemeral stream, which may be contaminating a larger area. Nitrate is mobile, especially in karst.

The well nitrate levels are much higher than mean levels in Big Creek, but not the nearby ephemeral stream. This eliminates the possibility that Big Creek is the source of nitrate pollution in the well, but suggests a common local source for the ephemeral stream and the well.

Mean Nitrate Concentrations in Surface Water (mg/L)

Big Creek Upstream of C&H Farm (BC6)	Big Creek Downstream of C&H Farm (BC7)	Ephemeral Stream
0.123	0.266	0.882

Representative Nitrate Concentrations in Groundwater and Surface Water, 2019 (mg/L)

Groundwater, House Well	Big Creek Downstream of C&H Farm (BC7)	Big Creek Upstream of C&H Farm (BC6)	Buffalo River at Carver
0.8	0.4 – 0.5	0.1 – 0.2	0.05 – 0.15

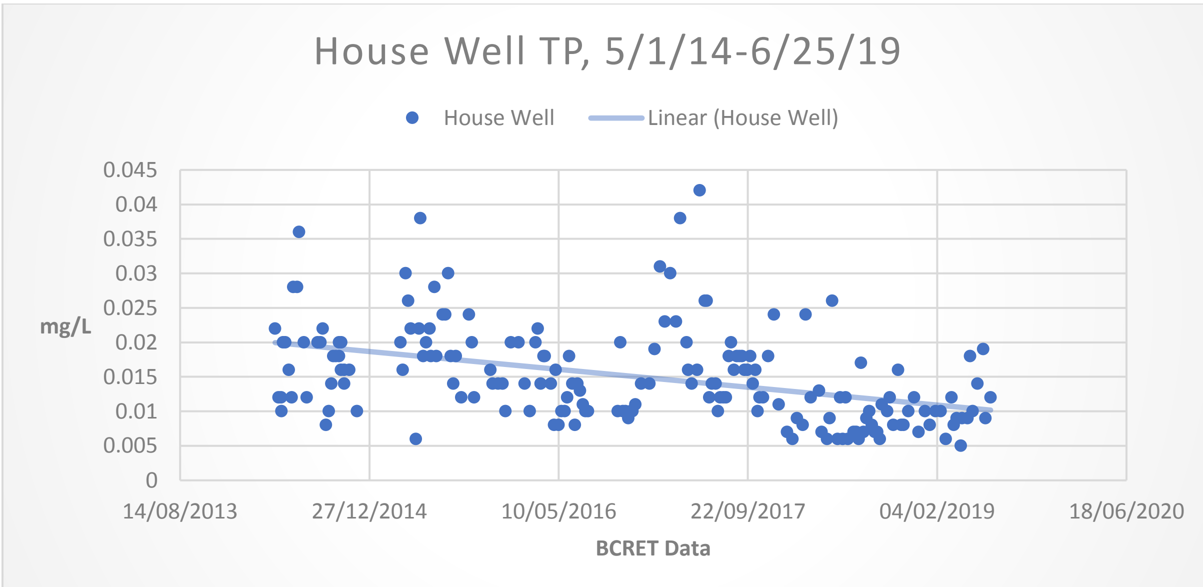


Figure 11. TP levels in the house well are low with little or no time variation after 2017 when some sample contamination problems were apparently solved. The trend line has no relevance given the change in methods. The real trend is stability with little deviation. Given the problems associated with sampling and/or analyses in the early part of the study, a data mean over the entire data set is probably unrepresentative of the actual average concentration over time.

Figure 11 illustrates lack of mobility of TP and the depth of the water intake at some 250 feet. If there is a TP plume developing around the swine waste lagoons, it would likely be expanding slowly, perhaps several feet a year.

Ephemeral Stream: The ephemeral stream drains a steep draw directly south of C&H, which sits on a ridge above it. It is short and flashy – dropping 409 ft in one mile and drains 0.17 square mile containing 38 acres of pasture (USGS StreamStats). It drains into Big Creek about a mile above BC7. There is surface flow only during wet weather, and therefore there is high flow sampling bias of the ephemeral stream in the BCRET data. The mean and median discharges at Mt. Judea for the BCRET data are 101 cfs and 26 cfs, compared to 157 cfs and 79 cfs for ephemeral stream sample dates.

Since the ephemeral stream (mean TP = 0.071) joins Big Creek downstream from BC6 (mean TP = 0.043), and upstream from BC7 (mean TP = 0.061 m/L), it is tempting to conclude that the ephemeral stream is a major contributor to the increase. But because of large variances, TP levels at BC6 and BC7 are statistically not significantly different from the ephemeral stream (p = .1 and .26, paired difference test).

Mean Nutrient Levels in Surface Water (sampling biased for high flow conditions)

	Nitrate	Phosphorus
Above C&H, Big Creek	0.112 mg/L	0.043
Below C&H, Big Creek	0.263	0.061
Ephemeral Stream	0.882	0.071

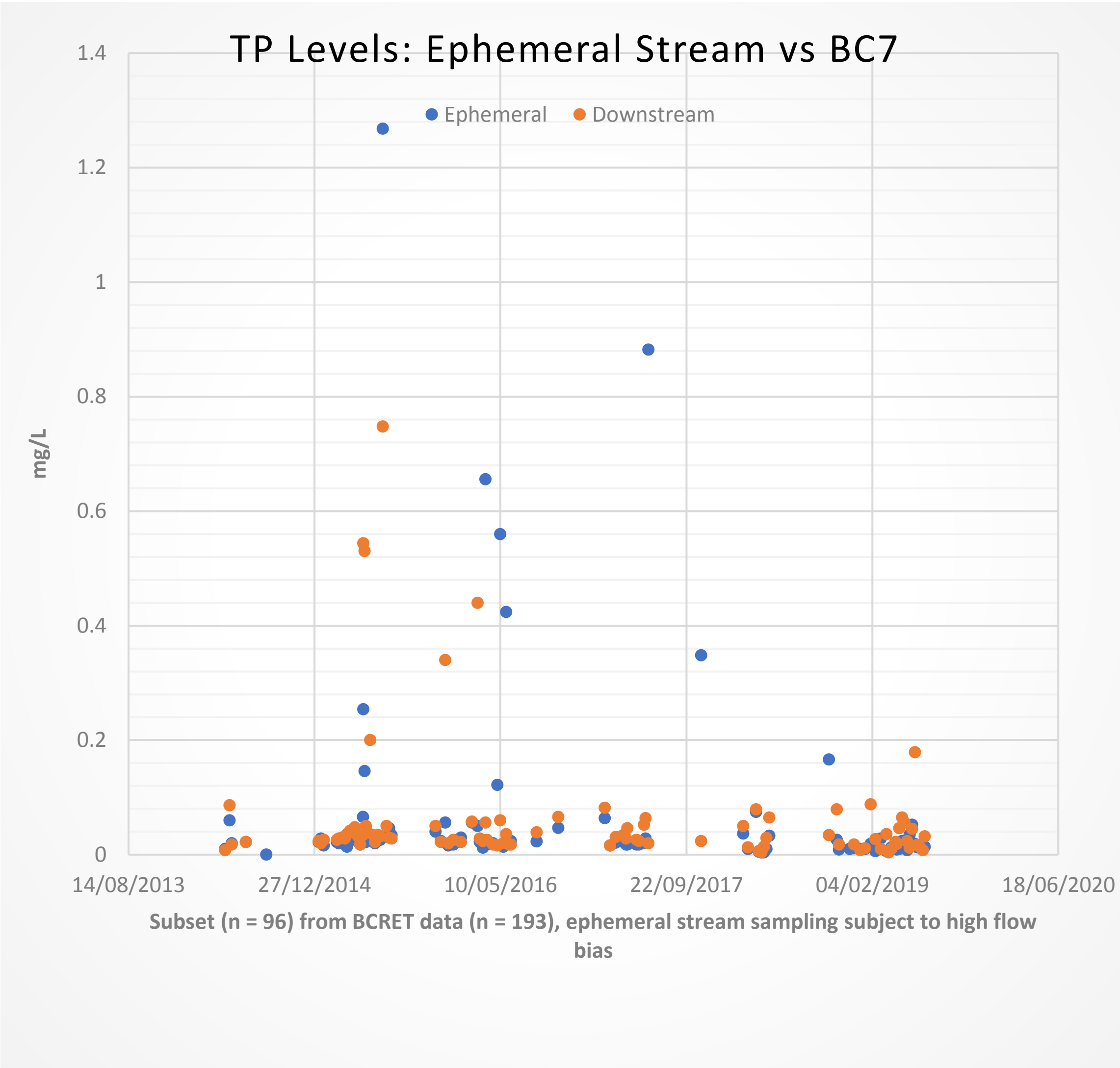


Figure 12. Because of the high flow bias, storm flows are over represented. The sampling data has a median of 79 cfs compared to 26 for the BCRET sample. The most important element of this graph is number of outliers with stream differences greater than 0.1 mg/L. But the outliers don't correlate strongly with BC7, 8 times TP at BC7 is lower by 0.1 mg/L, and 6 times higher than 0.1 mg/L.

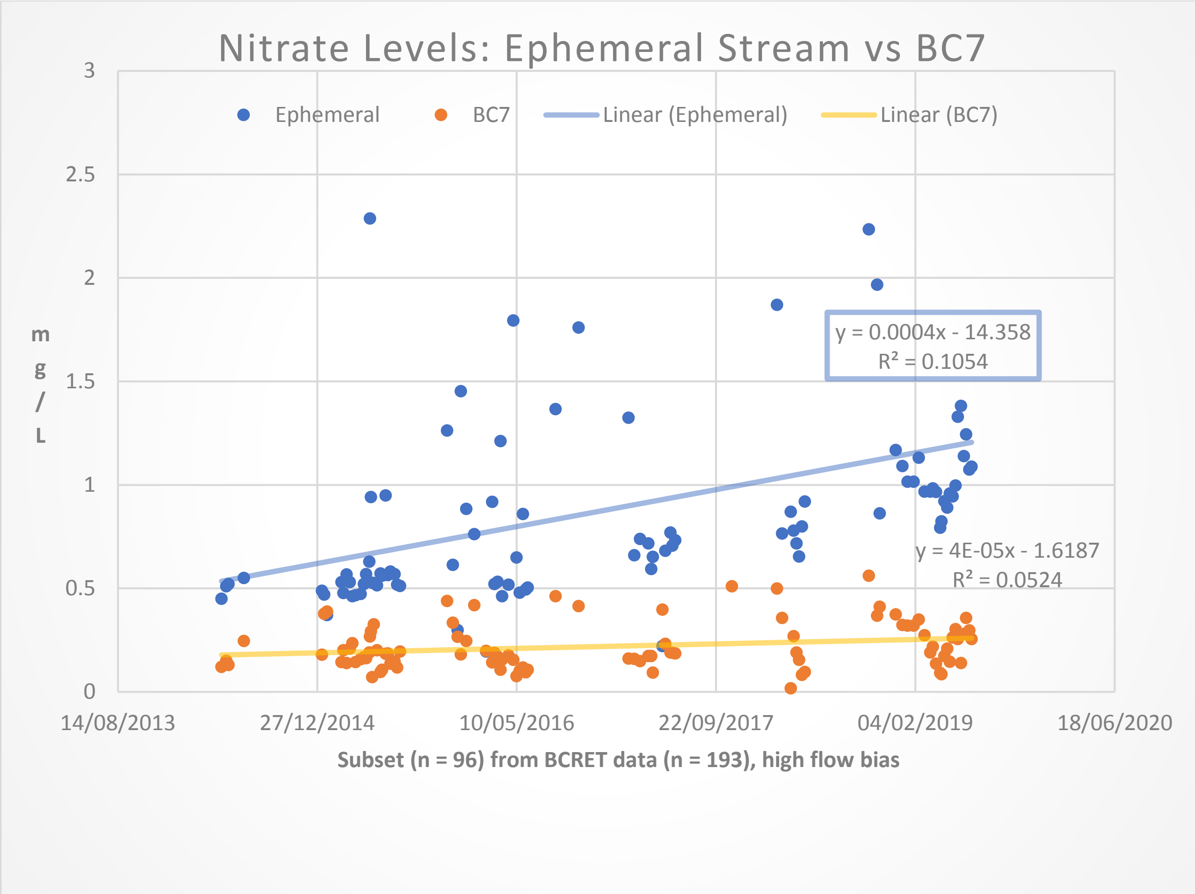


Figure 13. Because of the high flow bias, storm flows are over represented. The sampling data has a median of 79 cfs compared to 26 for the BCRET sample, but the presented sampling dates are the same for the Ephemeral Stream and BC7. For 95 of the 96 data points nitrate in the ephemeral stream is higher than downstream at BC7. Statistically, $p < 10^{-24}$ (paired difference test). The slope of the regression curve is 10 times that at BC7. 24% (23 out of 96) of the ephemeral stream samples are above 1 mg/L, which is considered to be the threshold of human health impact.

Notice:

- The slope the regression line for ephemeral stream nitrate is similar to that found in the house well, suggesting a common source,
- 24% of the sample values are above the human impact threshold of 1 mg/L, as in the recent data,
- The nitrate contamination at this level in mostly local, since there is no similar trend at BC7,
- There is one outlier, not shown, nitrate = 5.8 mg/L, TN = 9.820, on 10/23/17, which approaches levels found in the Iowa hog farm belt.

Conclusion: Unusually high and ever-increasing nitrate levels in the ephemeral stream, together with a similar trend in the house well, point directly to C&H Farm and its swine waste lagoons as a primary source of nitrate pollution. If there is an alternative source independent of the farm, its impact was oddly initiated just when the farm started.

E. coli: During the BCRET sampling period, Shawn Hodges of the National Park Service (NPS), Buffalo National River, was also collecting weekly data on Buffalo River tributaries and the Buffalo River above and below Big Creek. The NPS collection days did not generally coincide with BCRET days but a cross-check showed generally similar trends.

The subset of E. coli data (n =171 out of 196) in the BCRET data does not have a flow bias such as was found for the ephemeral stream. This is relevant since E. coli levels are correlated to stream discharge (figure 14).

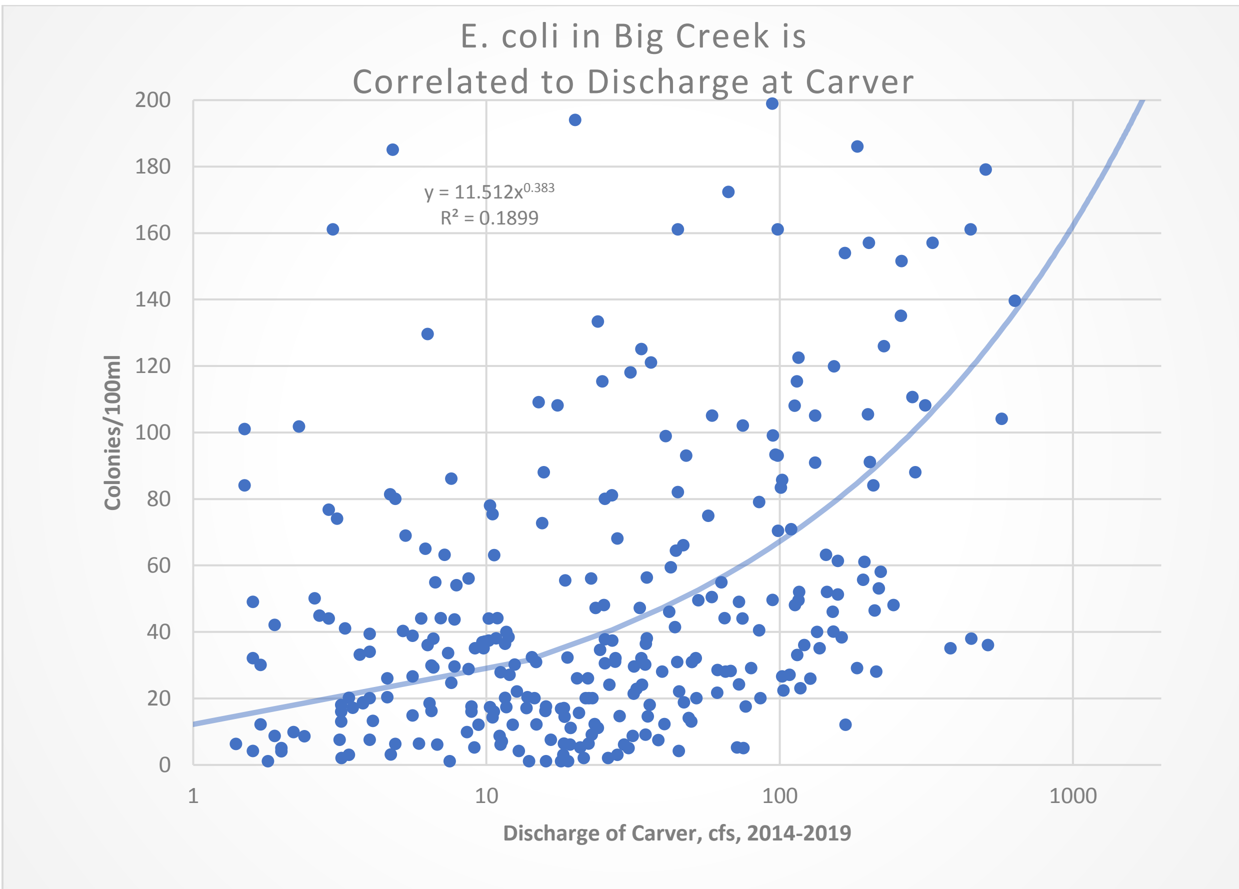
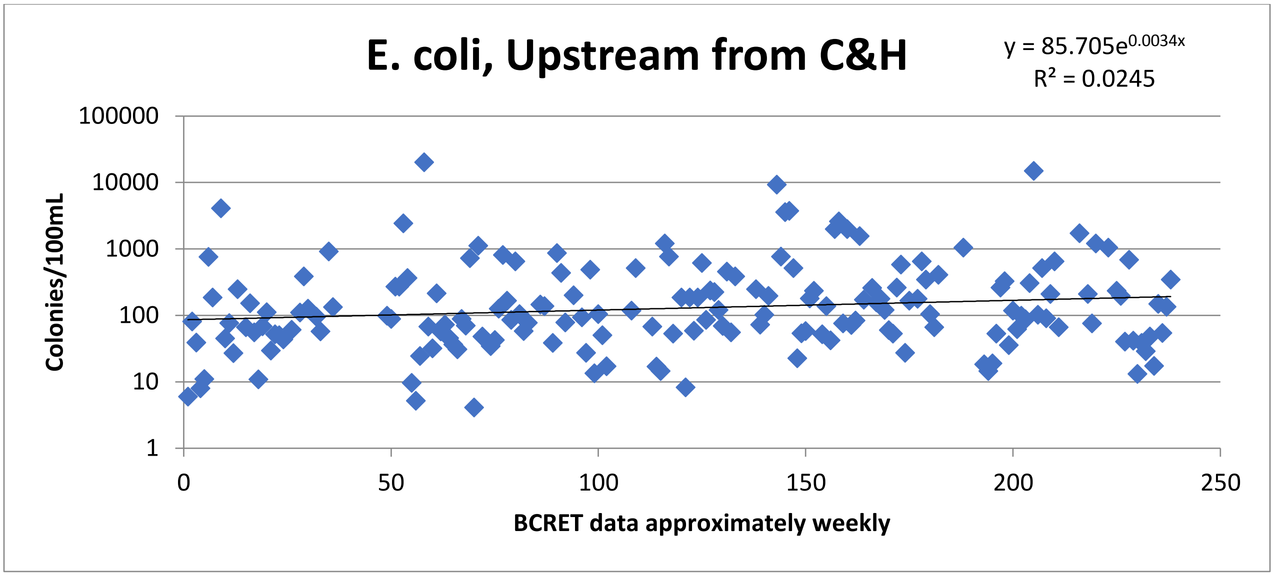


Figure 14. E. coli is correlated to discharge, R^2 = 0.19, but there are plenty of other variables involved – rainfall intensity, farming practices, temperatures, wildlife, etc. Some of the E. coli levels get extremely high even at modest discharge levels (< 100 cfs), this graph was truncated at 200 colonies/100mL. 28% of the samples from Big Creek at Carver were above 100 colonies/100ml.

Although not at all apparent in the graphs for Big Creek at BC6 and BC7 (figure 15) which appear to be random noise there is somewhat of a seasonal trend in E. coli levels with minimums in winter and maximums during the growing season with warm weather and maximum field work.



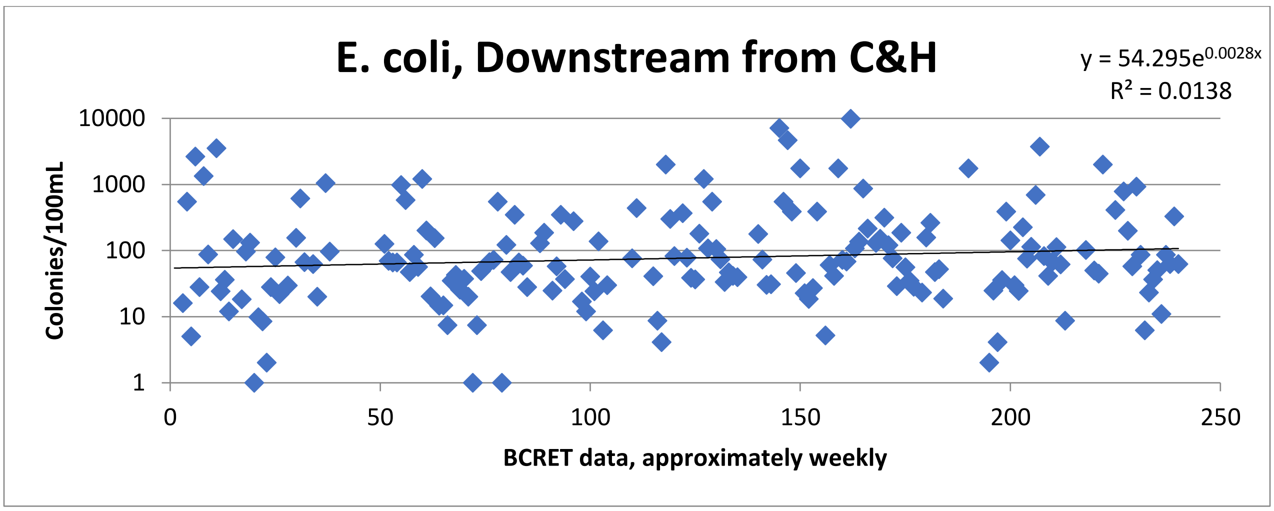


Figure 15. E. coli fluctuates widely with frequent values above 106 colonies/100ml. A 5 sample geomean above 106 colonies/100ml implies a 3% infection rate and a possible "impaired stream declaration." Upstream geomeans are 40% higher than downstream: upstream geomean = 160 colonies/100 mL, downstream geomean = 97 colonies/100 ml.

Curiously and counter-intuitively, E. coli levels in the Big Creek watershed decrease going downstream to and including the Buffalo River.

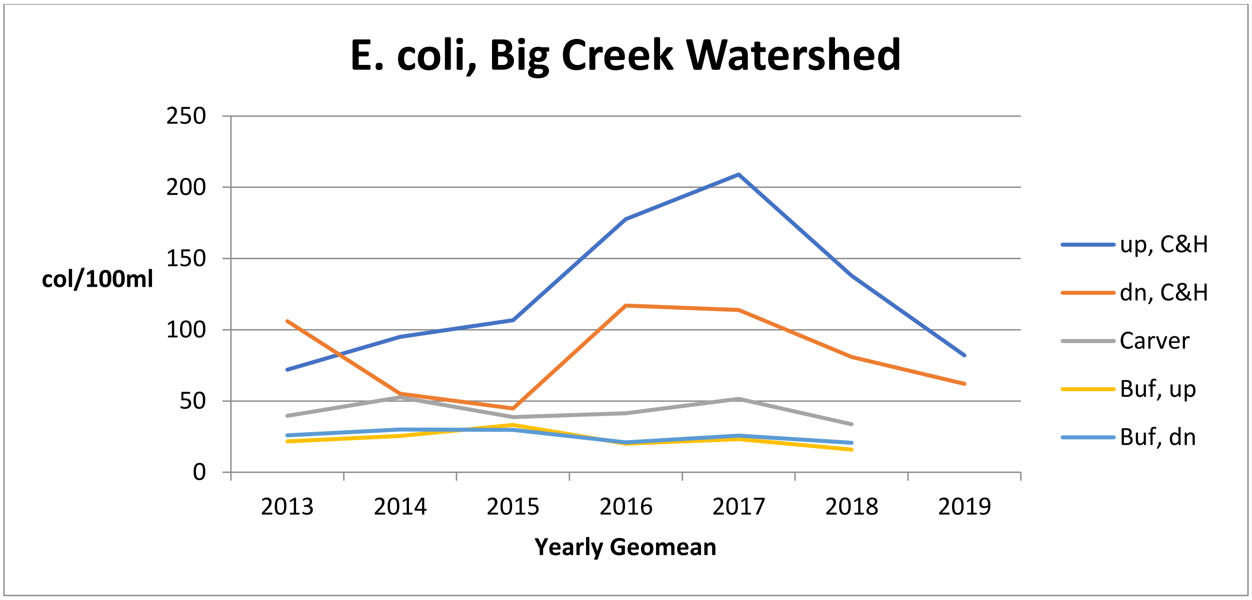


Figure 16. The main trend is that E. coli decreases as one proceeds down the Big Creek watershed, possibly due to dilution. The seeming decrease in levels during 2019 might stem from only partial year reports not a real trend. Note that Carver E. coli levels on Big Creek are twice those of the Buffalo, and at the confluence dilution does seem to lead to a limited 10-20% increase downstream. "up, C&H" is at BC6 , "dn, C&H" is at BC7, "Carver" is Big Creek at Carver near the Buffalo River.

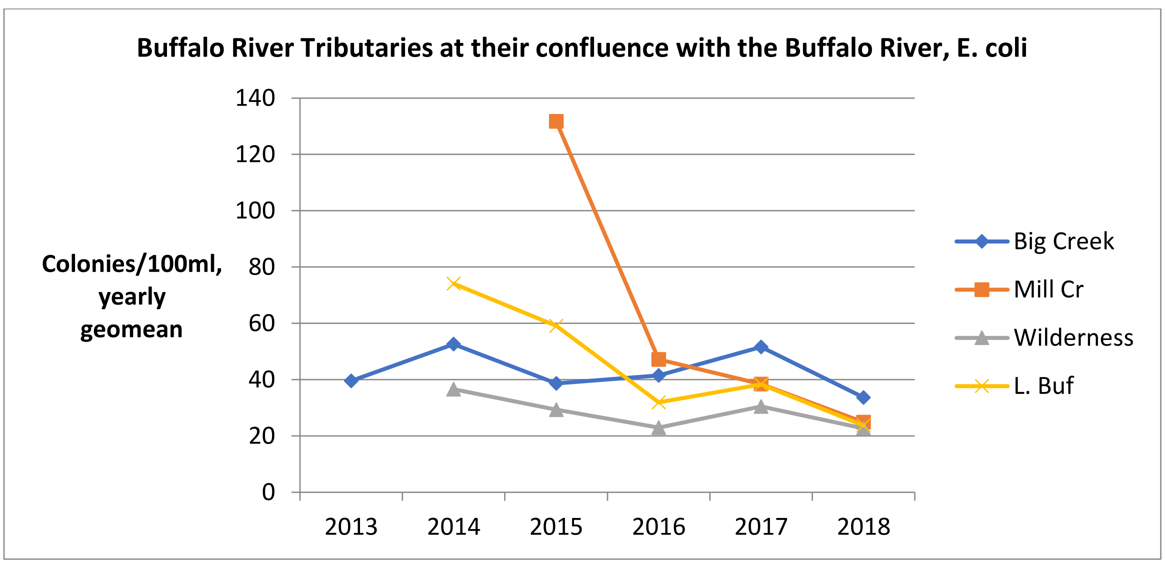


Figure 17. For a long time, E. coli on Mill Creek has been a major problem. But in the last two years Big Creek has had higher E. coli levels than all other upper river tributaries. (BNR data, Shawn Hodges). "Mill Cr" is Mill Creek, "Wilderness" is the Buffalo River sampled in the Upper Buffalo Wilderness, and "L. Buf" is the Little Buffalo River

Yearly Loads: The yearly load of a stream is the total nutrient mass passing a location in one year. A cumulative loading graph shows the cumulative mass over time. As will be discussed in section II, load estimates, which are products of both discharge and concentration, are difficult to estimate accurately because the concentration data is sampled weekly rather than instantaneously as is the case for discharge (e.g. every 15 minutes). Discharge data without the corresponding concentration data creates considerable uncertainty in the estimation of load. Load estimates are particularly sensitive to storm events, but weekly sampling means that approximately 6 out of 7 storms are missed, and must be estimated (modeled) in some way.

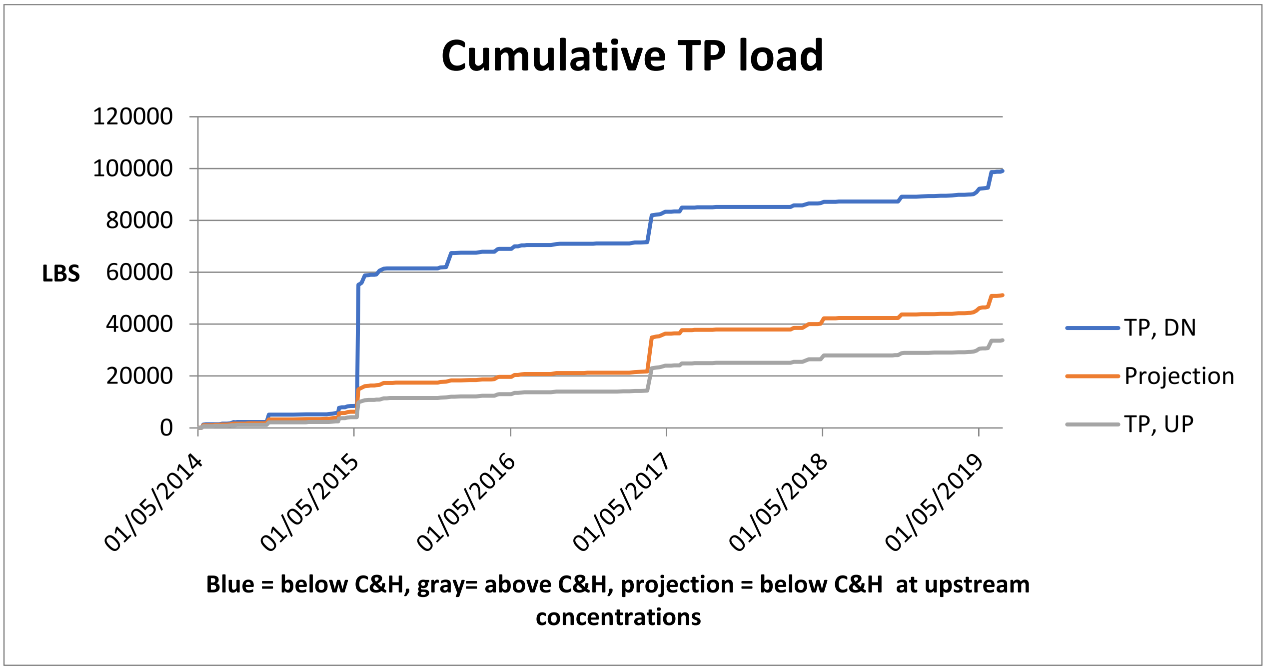


Figure 18. Cumulative TP loads below C&H (DN), above C&H (UP). The projected load is the load that would result if the TP concentrations upstream were applied downstream. The projected load basically assumes that land use above the farm is continued as Big Creek passes by C&H. The effect of storms is evident.

The most important part of the graphs is the difference between the blue and orange curves which can be interpreted as the result of more intense land usage in the farm stretch. For TP this difference is about 50,000 lbs, about 10,000 lbs/year. By way of comparison, C&H applies about 26,000 lbs of TP per year on its fields. The approximate difference, 16,000 lbs, is either exported in agricultural product or wildlife, or is fixed to soil particles in the spread fields.

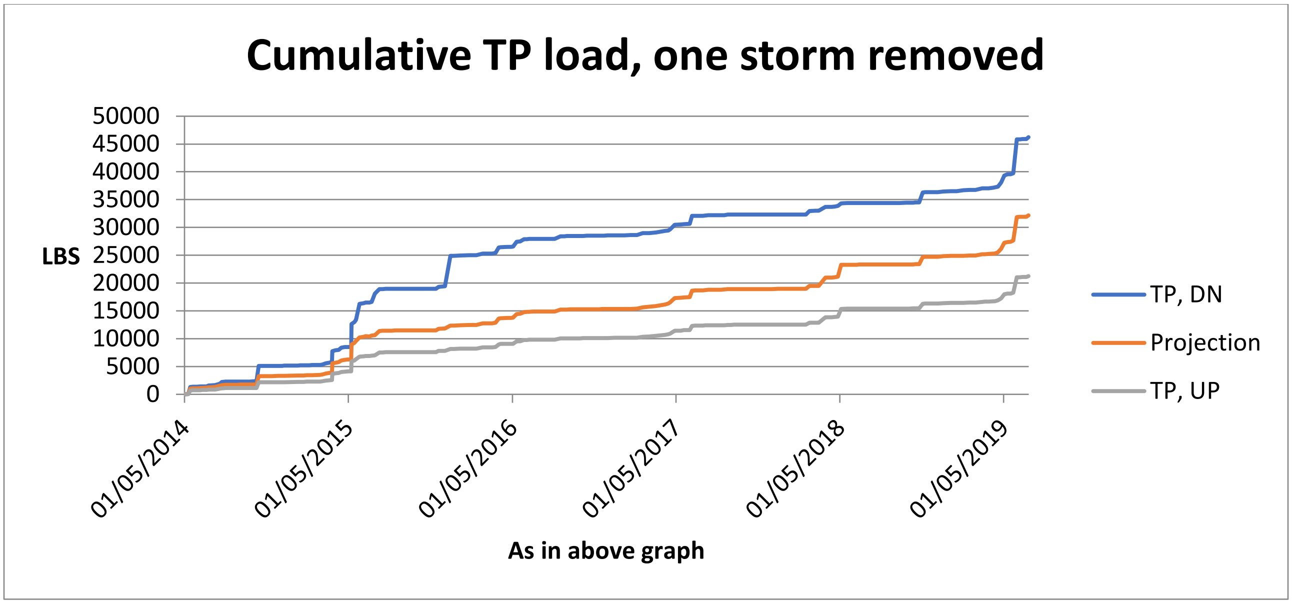
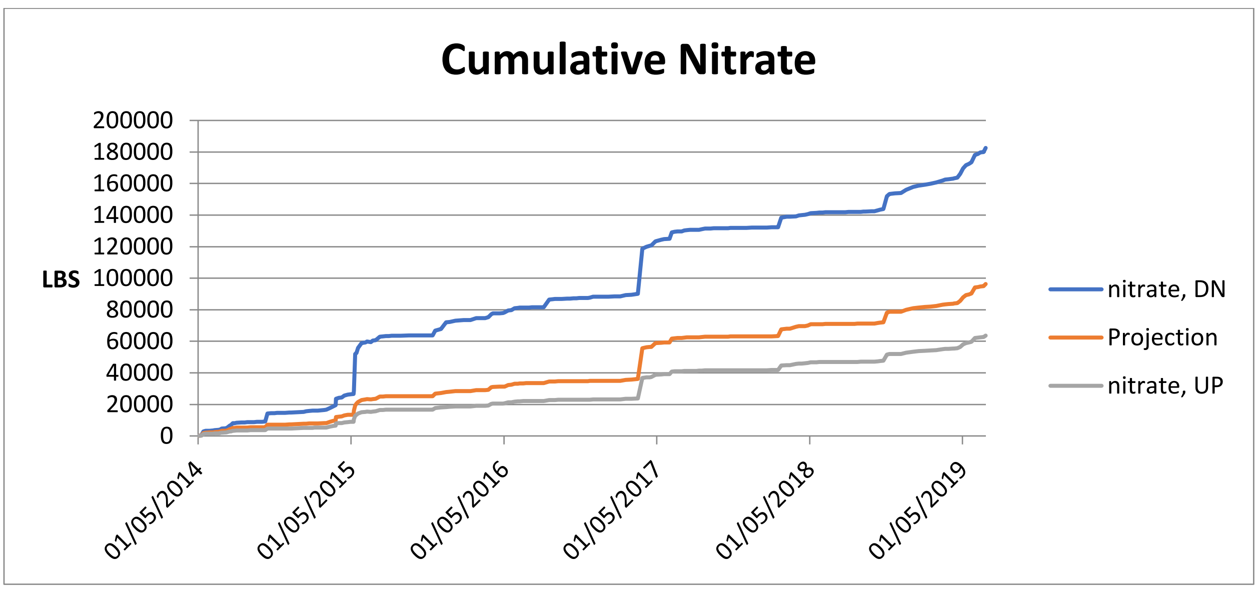


Figure 19. Removing one massive storm makes a significant difference.

Nitrate concentrations are negatively correlated with discharge while TP concentrations are positively correlated to discharge. Therefore, nitrate loads are not as sensitive to storms as TP loads (figure 20).



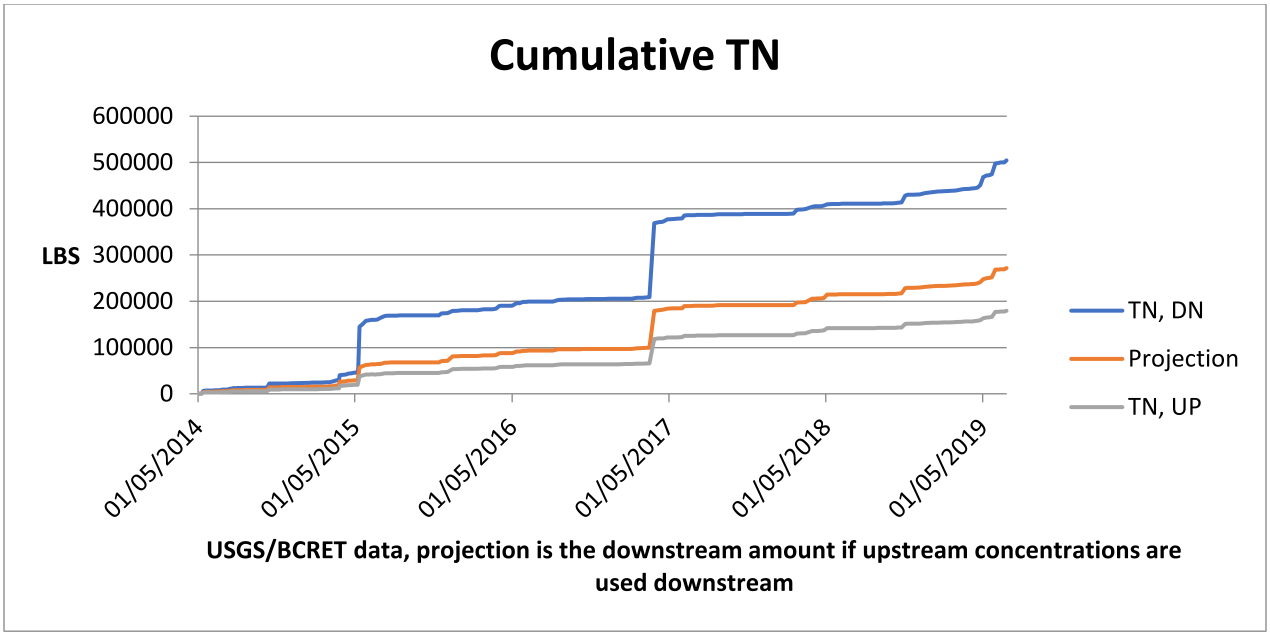


Figure 20. The two graphs are similar with two jumps in the data correspond to the two large storm events that were "caught" by BCRET in their grab samples. The five year difference in nitrate load between the blue and orange curves is about 85,000 lbs, or 17,000 lbs/year. C&H produces about 60,000 lbs of nitrate a year but denitrification, agricultural production, and volatility of ammonia accounts for much of the loss other than in streams.

Since nitrate is a subset of TN, the graphs should have similar shapes, but there is an additional effect that may be correlated to land use, e.g. forest vs pasture, and farming practices. Above C&H the nitrate/TN ratio is 46% while below C&H the nitrate/TN ratio is 64%.

Critique: **Surface Runoff from Application Fields and Relationship to Field Management**

A main objective for this chapter, and five years of experimental work on fields 1, 5a, and 12, is the generation of the percentages of applied phosphorus in runoff, 0.8, 6.6, and 2.2%, in column 6, and the percentages of applied nitrate in runoff, 1.8, 4.4 and 4.5% in column 9 of page 15, see below. These percentages of applied nutrients in runoff are not out of line with other regional studies.

Table 7. Loss of P and N in runoff from fields in northwest AR and eastern OK and losses from Big Creek Fields B

Site	Site years	Management	P applied	P runoff	% applied in runoff	N applied	N runoff	% applied in runoff
			lbs/ac/yr			lbs/ac/yr		
BC1	5	Grazed pasture with swine slurry	94	0.78	0.8	100	1.82	1.8
BC5a	5	Fertilizer grazed and hayed pasture	25	1.65	6.6	57	2.49	4.4
BC12	5	Grazed and hayed pasture with swine slurry	75	1.67	2.2	90	4.04	4.5

Given the use of commercial fertilizer on field 5a and the use of hog waste slurry on fields 1 and 12, these data might be considered useful by some in comparing the relative potential of nutrients from two different sources to runoff fields and thus be part of a continuing discussion over the environmental merits of hog manure verses commercial fertilizer. But in this case the focus is on TP and the implied premise below that may be misconstrued from the result.

Premise: Over 5 years, even with TP application rates far above agronomic needs at C&H, only 0.8% and 2.2% of the TP applied in hog slurry in fields 1 and 12 ran off the fields, whereas 6.6 % of the TP in the commercial fertilizer in field 5a ran off. Therefore, TP in swine waste slurry applied to fields runs off of fields to a lesser extent than fertilizers and therefore, is protective of streams.

Conclusion: The Ozark Society will argue that the experimental design was flawed from the beginning, that the crucial numbers in columns 4 ("P applied") and 5 ("P runoff") cannot be considered accurate and may be wrong by factors of 3 or more, and that a significant weather event was inappropriately included in the data analysis. Therefore, this chapter adds no useful information to determine whether or not hog waste slurry is environmentally superior to commercial fertilizer in protecting streams from TP runoff.

To be fair, the notion that excessive application of TP, which is the swine CAFO model, is good for the environment, is refuted several times in the report. "Future additions of any nutrients … to fields, which received slurry from C&H, should be carefully managed, so as not to lead to further increases in soil test P. This can be achieved by application of Nitrogen (N) fertilizer or slurry and poultry litter at P-based rates, where P applied is equivalent to expected forage rates of P." [P. 7, Final Report]

Frame of reference: the agronomic P need for a grazing cow and calf pair is about 10-20 lbs/acre, while on page 8 of this chapter we find the estimate that field 1 received 232 lbs/acre of P in 2017. For reasons discussed below, the estimate of field applied P to field 1 is unreliable if not wildly wrong on the high side. This should not be misconstrued to mean that P was not over-applied to the C&H fields. It is quite clear to us that P was widely over-applied to the C&H fields. However, we find that some of the estimates of the amounts of over-application of P are incorrect.

The chapter, "Effect of Slurry and Field Management on Soil Nutrients" details the increase in TP over time in fields 1 and 12, but decreases in field 5a. Is this due to excessive TP application or is this because P just runs off field 5a because the manure is not there to hold it? This is part of the argument: application of manure increases the storage capacity for P in the spread fields.

The experimental method in this chapter is common. The Arkansas Phosphorus Index relies primarily on experimentally estimated runoff:input ratios, as in column 6 above, refined down to soil type, slope, application timing, artificial rainfall events, crop type, buffers, fence lines, ponds, etc. One issue with these indices is whether the small experimental plots represent actual overall field conditions, as in this case. Without trying to do a detailed error analysis here are some of the problems.

- Soil Test P (STP): TP is available from two sources, the applied slurry or commercial fertilizer and the TP that is already in the soil (STP). It is possible that even with no commercial fertilizer or slurry recently applied, a field could have the highest yearly runoff load because of high STP. Furthermore, with continued overapplication of TP, STP levels increase and become more important. For this reason, there should be another column in table 7 for the base amount of STP. Without consideration of the base amount of STP present prior to application, the estimation of percent TP applied that runs off (column 6) is probably erroneous. Contrary to the methods of BCRET the analysis of percent P in runoff is not as simple as dividing column 5 ("P applied") by column 4 ("P runoff").

- Topography: The land treatment on field 5 might be important and the drainage might include the road and beyond. The catchments in both field 1 and 12 (P. 4,6) are both in buffer zones which received no slurry applications and might actually buffer nutrient runoff.

- The nutrient content of the manure slurry: The entire numerical argument hinges on an accurate estimate of TP in the applied slurry. But.

    i) The nutrient analysis of the lagoons from C&H annual reports is dubious. The data from the annual report also doesn't jibe with that found in the final report, which doesn't differentiate between the lagoon sources.

Annual reports
Pond 1

	2013	2013	2014	2014	2015	2016	2017	2017
N lbs/1000 gal	9.5	16.8	33.1	20.1	20.1	15.7	24.8	22.4
P_2O_5 lbs/1000 gal	10.1	18.1	55.6	4.8	4.8	21.6	30.4	29.9

Pond 2

	2013	2013	2014	2014	2015	2016	2017
N lbs/1000 gal				7.2	15.2	8.7	3.8
P_2O_5 lbs/1000 gal				8.7	7.9	1.8	2.9

BCRET final report

Site	2014		2015		2016		2017		2018	
Slurry applied, gals										
Field 1	46,000		12,000		78,000		60,000		57,000	
Field 12	48,000		93,000		156,000		90,000		105,000	
Nutrients applied in slurry, lbs/1000 gallons										
	P	N	P	N	P	N	P	N	P	N
Field 1	4.8	20.1	4.8	20.1	17.5	30.3	60.3	47.2	12.4	12.2
Field 12	4.8	20.1	4.8	20.1	17.5	30.3	60.3	47.2	12.4	12.2

ii) Is it likely, or even physically possible, for TP in lagoon 1 to go from 55.6 lbs/1000 lbs to 4.8 lbs/ 1000 gallons in one year? Over 5 years, the N:P ratio, p. 9-12, steadily and implausibly decreased from 4.19 to .76. These questionable numbers are the basis for the conclusions.

iii) Fluctuating lagoon nutrient levels are not unusual. For long term monitoring, a 5-year moving average can be used. For the annual report data, the averages are, 20.1 lbs/1000 gal for nitrate and 21.9 for phosphate, a N:P ratio of about 1. But then some of the input numbers in this report would change by a factor of 3-4.

iv) But this would not solve the problem of stratification in the lagoons, and the precision needed by honey wagon operators to get a representative sample spread on the fields. The best way to eliminate all these problems is to sample the slurry trucks as they go to fields 1 and 12, but this was not done. The only reliable application rate estimates of TP in this study are for 5a which remained at 25 lbs/acre throughout.

v) Bad luck with the weather. During the very high runoff event in 2015, as recorded by ISCO samplers, field 12 had about 139,000 cubic feet/per acre in runoff (38.4 inches deep/acre), field 5a had 74,783 cubic feet/acre of runoff (26 inches deep/acre), but field 1 only had 7881 cubic feet/acre of runoff (2.2 inches/acre). Is rainfall, and consequent runoff really that spotty, a factor of 17 within 2.5 miles, or are there other factors like slope and instrumentation ineffectiveness involved? In this case, fields 5a and 12 were flooded by overflow from Big Creek so the very large numbers in column 6, page 10, which dominate the conclusions, don't represent runoff from the field and are too unwieldy to be sensibly included.

Conclusion: Although the report dedicates much discussion to the estimation of P runoff from fields 1, 5a, and 12, there is insufficient information available (i.e., the lack of TP in the fields prior to applying swine waste slurry or commercial fertilizer) to confidently perform the analysis. Furthermore, the limited analysis presented by BCRET relies heavily on estimates of P in swine waste slurry that are highly variable, a fact likely due to unrepresentative sampling of the swine waste slurry. Lastly, widely varying estimates of surface water runoff from the fields (a factor of up to 17 fold different) during the same runoff event suggest the potential for sample equipment malfunction or the failure of the analysis to quantitatively account for other important but apparently unknown

factors affecting runoff (such as field slope). In the face of these insufficient or invalid inputs, we have no confidence in the BCRET estimates of phosphorus runoff from fields 1, 5a, and 12.

Critique of Chapter 7: **Nutrient Loads in Big Creek Up and Downstream of C&H Farm**

The total mass of nutrient, the load, transported in a stream over a time period, say a year, can be important for several reasons.

i) Phosphorous is largely responsible for the dead zones in the Gulf of Mexico and elsewhere and has been found to contribute to an algae problem. One estimate is that 5% of the TP in the Mississippi River comes from Arkansas agriculture.

ii) An estimate for the nutrient load from the C&H farm section between BC6 and BC7 could be used to analyze the impact the intense farming practices between BC6 and BC7.

This is the indirect gist of chapter 7 as presented in the amended BCRET final report but no estimates for C&H's contribution to nutrient loads were attempted.

Conclusion: Loads are notoriously difficult to estimate accurately given only weekly point estimates for nutrient concentrations, especially for dP and TP. BCRET only sampled about 30% of the major storm events and did not generate a model for TP runoff from storm events, but relied on a USGS model which sought to predict load using two physical parameters, instantaneous discharge Q and decimal time. The Ozark Society presents another method using flow weighted means. The methods roughly agree.

Background

The general assumption for this chapter is that the watershed is a mechanical system that will respond characteristically to various inputs: runoff, rainfall intensity and location, watershed shape, soil infiltration rates, slope, temperature, plant absorption, livestock and animal behavior, spread field cover, timing and intensity of agricultural waste, leaky septic tanks, frozen fields, and so forth. Models simplify things, thus helping to make predictions. In this case, all these variables that affect load are captured by three parameters, A, the exponent b of Q, and the less important but not irrelevant α.

$$\text{Load} = A * Q^{b} * e^{\alpha * \text{dtime}}.$$

Some aspects of this model lead to uncertain estimates.

- It is just a model. The numbers presented for monthly loads do not necessarily represent real loads. Curiously, although BCRET performed no sampling during the large storm that peaked at more than 8000 cfs on December 28,2015, the model nonetheless predicts a large TP load of 3809 lbs for the month, 29% of the yearly estimate.

- For storm discharge, a power model may not a good predictor for nutrient concentrations, see figure 1 below. There is a general pattern, the regression curve is somewhat descriptive, but the variation from these curves can be large.

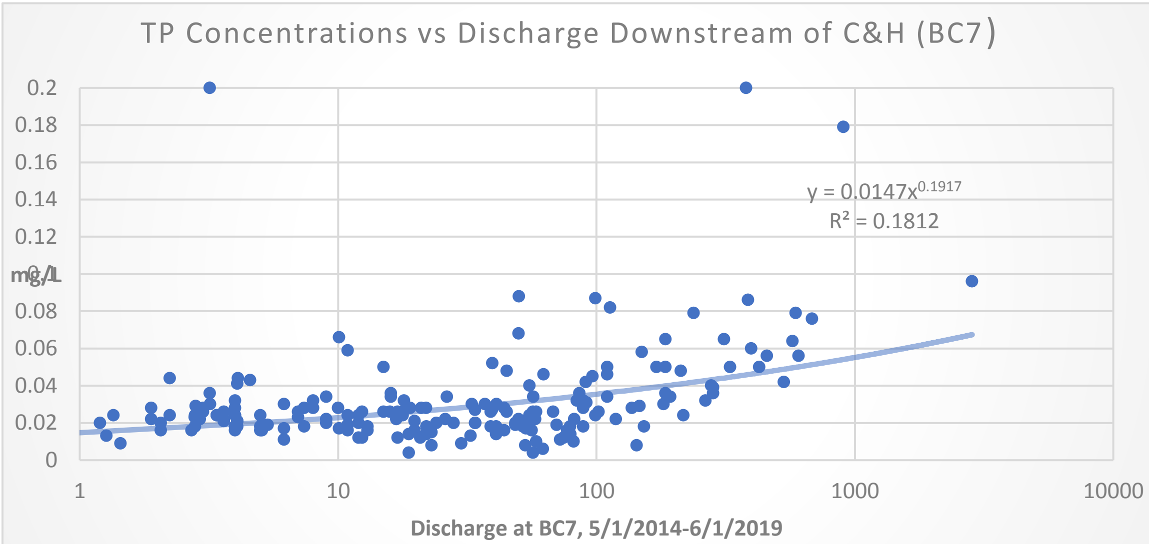


Figure 1. TP is positively correlated with discharge because TP concentrations generally increase with discharge. Statistically this is measured with the positive exponent b = 0.1917 in the power regression curve. However, the fit is not particularly good since at both BC7 and BC6, TP levels are essentially flat and the same, up until about 100 cfs. The 7 outliers (only two shown), carry a large share of the TP load as emphasized in the BCRET final report. Smoothing techniques, or looking at only base flow, could introduce large errors in load estimates.

- BCRET had no apparent success in modeling individual storms and there may have been no calibration of the model, i.e. comparing predictions to actual storm events. See page 8 of the BCRET report for confusion on this point.

- BCRET gives no error analysis

- The graphs and the tables of comparisons beginning at page 14 are a nice touch but don't really get at the issue. The issue is: Are the nutrient loads produced between BC6 and BC7 significantly higher than those ambient levels found above BC6, i.e. above the farm? For instance, on page 22 the nitrate levels upstream and downstream in 2014 were modeled as 0.976 and 1.324 lbs/acre. From this it is possible to project the nitrate load between BC6 and BC7 would be 2.054 lbs/acre, more than doubling the ambient level.

A standard and accurate method for estimating load for one storm event is shown in a graph by David Mott.

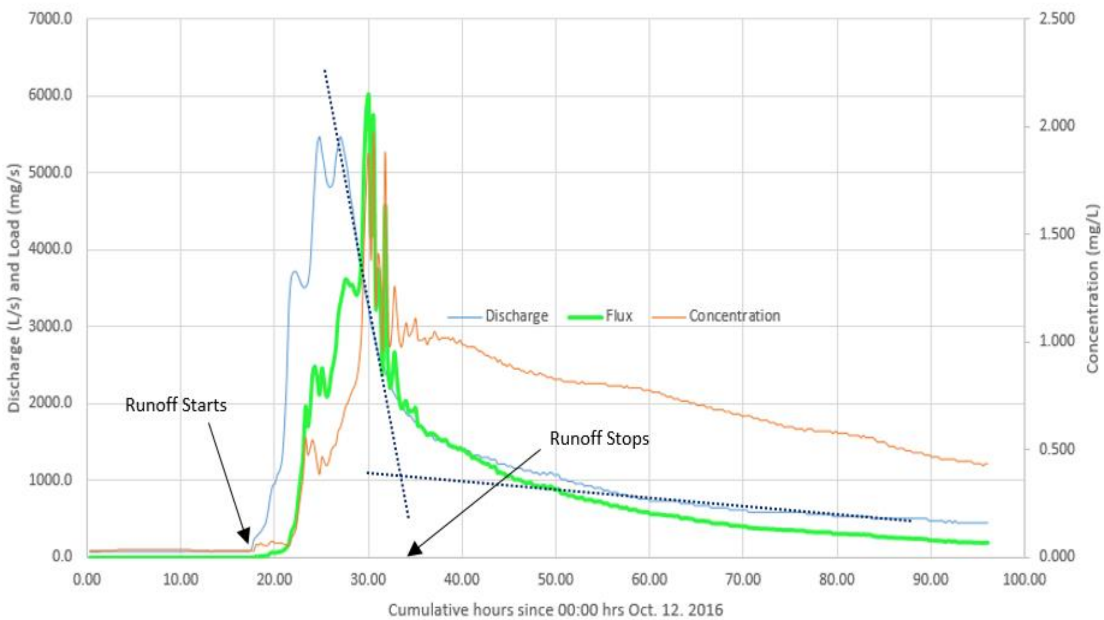


Figure 1: Behavior of discharge, concentration, and flux loads in response to an October 12 - 13, 2016 storm event at Big Creek at Carver (L/S = liters per second, mg/s = milligrams per second, and mg/L = milligrams per liter).

Note the following characteristics about nutrient and loading response curves:

- There is a time lag of several hours between the peak discharge (blue) and the peak nitrate concentration (orange). This suggests a direct nitrate runoff source of pollution several miles upstream, perhaps a spread field.

- The discharge curve (blue) is typical of Big Creek which is flashy, featuring very fast rises and characteristic steep exponential declines. The time for discharge to decrease to half from the peak (half-life), for the 11 large storm events in the 2018 water year, was stable: half- life ~ 10.9 ± 1.3 hours. Most storm discharge events are similar and of short duration, typically less than a day.

- When a storm event occurs, base flow increases. In this case from about zero before the start at 18 hours, to about 52 cfs after runoff stops at 38 hours.

- The discharge curve (blue) and the flux curve (green) are similar after runoff stops, because discharge is the dominant part of loading estimates. Nonetheless, the flux curve drops faster than the discharge curve because the nitrate concentrations (orange) are also decreasing.

The primary problem with estimating loads on Big Creek from BCRET data.

The loading estimate given by Mott for the Oct 23-24, 2016 storm is probably quite good: d(t) is accurate and c(t) is less so, maybe ±10% depending on the calibration accuracy. The EPA has estimated that 80-90% of nutrient loads come from storm loads. So, storm analysis is critical to an estimate nutrient loading to streams This is a major problem for estimating loads from BCRET data as it was collected. Nutrient concentrations c_j were collected approximately every week as grab samples with relatively little time delay between BC6 and BC7 – a good procedure in general but for storm estimates it is hit or miss. Of the 11 major storm events in the 2018 water year (discharge > 1000 cfs) only two were sampled, with a time delay of 10 hours and 3 hours from the peak discharge

As has been shown, installing automatic nitrate samplers at BC7 and BC6 might work but this apparently was not a financially or technically viable option. For TN and TP, a grab sample is expensive and sampling storm events every 15 minutes was inconvenient and not pursued. This is unfortunate since the analysis of several storm events might have provided a useful model nutrient response curve.

After the fact there are at least three different ways to get around this basic problem.

Method I – ISCO samplers

ISCO samplers estimate the flow weighted mean C during a storm event by varying the sampling frequency to match the discharge. A storm load is then the product of C and the total storm discharge which is readily and accurately available from the USGS. In order to be effective, ISCO samplers need to be carefully calibrated, maintained, and samples promptly retrieved after a storm event. It is possible that significant errors are introduced by the discrete sampling rates. The BCRET team tried ISCO samplers for some storm events but apparently found the results not of use in estimating loads.

Method II – Load modeling

Page 8 of chapter 7, explains that model 3 was chosen to best estimate loads. The numbers presented in the 2nd column are off by several orders of magnitude. The astounding range of predictions in the 2nd column also suggests that selection of models is an art rather than a science. The apparent chosen model for load L is (changing notation somewhat)

$$L = \text{Monthly load} = A * Q^b * e^{\alpha*\text{dtime}}$$

where Q is stream discharge, and α*dtime is a correction for seasonal variation. Despite the many pages of numerical results from this basic assumption, the numerical parameters A, b and α were not given. But with considerable effort it is possible to numerically deduce these parameters. For instance, for nitrate at BC7 during the water year 2014-2015, A ~ 38 lbs, b ~ 0.77, and α is evasive but small.

Load Modeling III It is useful to compare the results of the model 3 found in chapter 7 with a basic application of the formula

Yearly load = Yearly flow weighted mean x Total yearly discharge,

based only on BCRET grab sample data.

Downstream Load Estimate Comparisons

Water Year	Nitrate		TP	
	Model 3	**Flow weighted model**	**Model 3**	**Flow weighted model**
2014	18,446 lbs	16,814	4,972 lbs	5,524

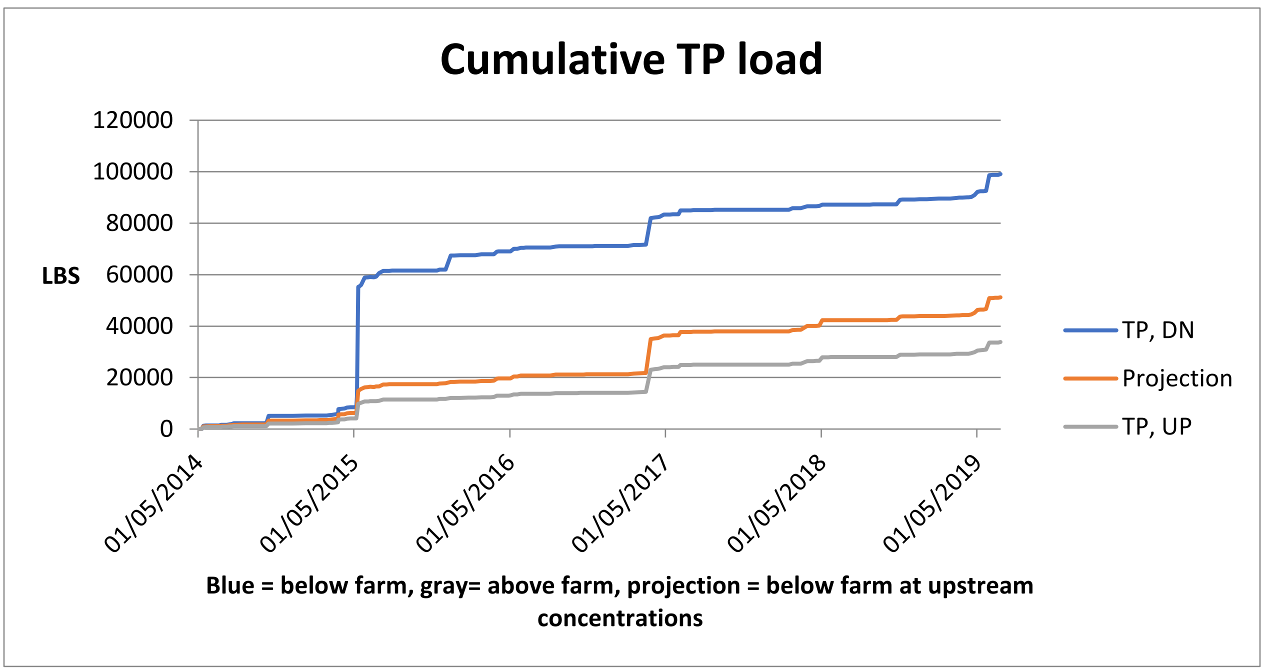
2015	32,973	41,703	13,085	44,104 *
2016	24,915	23,094	6,040	7,437
2017	23,396	30,047	5,046	7,045
2018	32,138	28,078	4,988	9,097
Mean	26,373	27,947	6,826	7,937-14,641

*(10,584 with May12 removed)

Table 1. Comparison of two different methods for estimating loads. Load estimates for nitrate are likely to be more accurate than for TP. The large variation suggests not drawing conclusions from the numbers presented in Chapter 7. The consistently larger TP load estimates from the flow weighted model might partially reflect a bias toward high discharge in the BCRET sampling procedure (e.g. incomplete data during very low flow and occasional impromptu sampling of storm events). There is no accurate way to assess the TP load for the two major storms in 2015.

Conclusion: Different load models produce estimates of loading that vary considerably, especially with TP because of its increased surface mobility primarily during storm events.

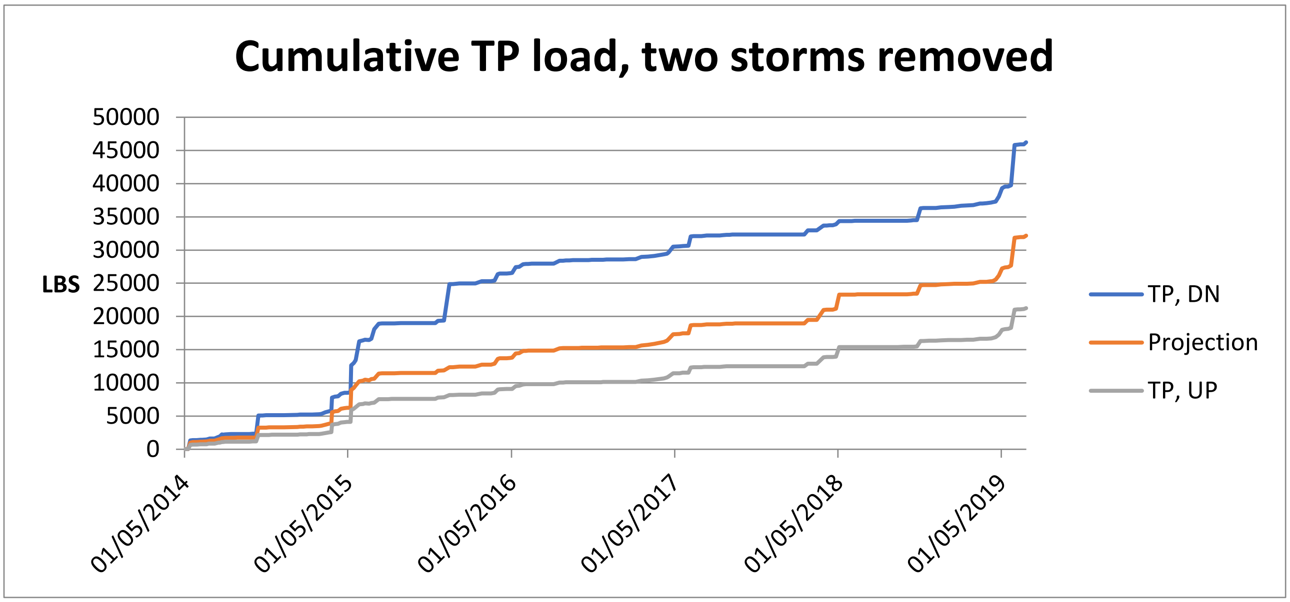
The inclusion of cumulative graphs in the Final BCRET Report is a good visual way of illustrating storm effects and the differences in nutrient responses above and below the farm. Even better is the inclusion of projection curves as in the next three graphs.

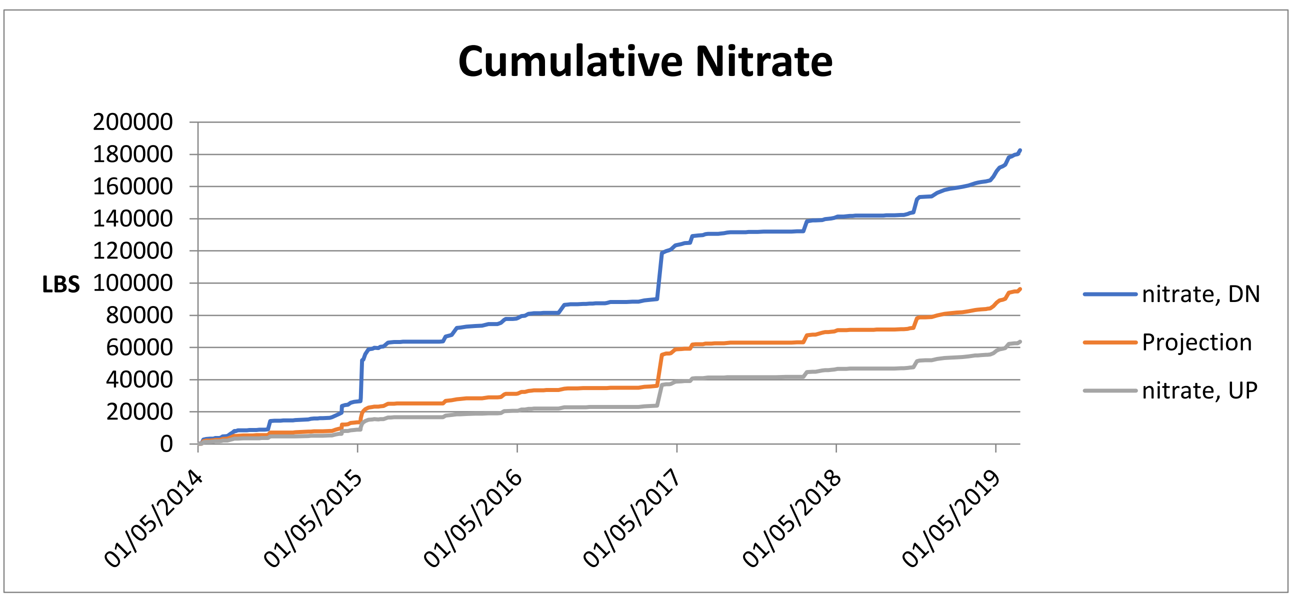


Cumulative TP loads below the farm, above the farm, and the projected load at BC7, if the concentrations upstream were continued downstream. The projected load at BC7 assumes that land use above the farm is continued as Big Creek passes by the farm. The effect of storms is evident. The impact of the December, 2015 storm is missing since there is no data point in the BCRET data.

The most important part of the graphs is the difference between the blue and orange curves which can be interpreted as the result of more intense land usage between BC6 and BC7 by C&H and other farms and Mount Judea. The large jump on 5/11/2015 is the previously discussed difference in upstream and downstream load on that date – one storm and one data point.

The next two cumulative graphs illustrate the removal of the largest storm in the case of TP, and the similar results for nitrate, probably more accurately.





Critique: **Nutrient Concentrations in Big Creek Correlate to Regional Watershed Land Use**

The basic idea is obvious – runoff from developed land is likely to have higher nutrient concentrations than from undeveloped land. In this case the notion of developed land is - percent of pasture plus urban. By comparing tributaries in the Upper Illinois River, Upper White River and the Buffalo River the researchers then produced exponential curve fits between pasture/urban areas and nutrient levels. It is possible to nitpick the methodology:

- The model was insensitive to intensity of development. For instance, one square mile of C&H or downtown Jasper was judged to have the same impact as 200 cows on 640 acres of mixed cool weather grass.
- Although conservation of mass arguments imply a bilinear response for each added acre of development, the BCRET team inappropriately chose exponential models.
- The exponential models produced strange results. Although it is always true that nitrate is less than TN, using exponential models the nitrate best fit curve crossed the TN best fit curve. Hence predicting that at certain levels of pasture usage, nitrate > TN.
- It was not clear why the Illinois River watershed, having been assaulted by excessive TP levels for many years, would be thought to shed light on Buffalo River tributaries, **except** it is a good reminder of why a permanent moratorium on medium and large hog farms is needed in the Buffalo River watershed.
- The input data as published in BCRET quarterly reports included sums of land use substantially less than 100%, and all too frequent instances of dP > TP and nitrate > TN. In the Buffalo River Watershed this is attributable to dissimilar collection times, i.e. not paired data.
- In the Buffalo River watershed, the data was collected sporadically during base flow (quarterly sometimes) over 25 years. In these 25 years some sample sizes were sparse, less than 10.
- As we have seen, tributary samples at the confluence with the Buffalo River do not necessarily predict upstream concentrations – e.g. E. coli in Big Creek.
- A tributary site was oversampled when a problem occurred.
- The data used by BCRET for the comparative analysis was outdated.

That having been said, the BCRET conclusion that sticks in average Arkansan's throat is: "At this time, nutrient concentrations in Big Creek upstream and downstream from the swine CAFO are consistent with the range in concentrations for other watersheds with similar pasture and urban land use characteristics [exponential curve fits], as well as less than most nutrient thresholds for nuisance water-quality conditions." By this statement, the authors of the BCRET report seem to suggest that the Big Creek watershed, and by extension, the Buffalo National River watershed of which it is a part, deserve no more protection from nutrient pollution than other watersheds in Arkansas. Following this logic, the Buffalo National River watershed should be impaired only as much as other watersheds in Arkansas. We must wholeheartedly disagree and believe that Arkansans must protect our first national river from operations such as C&H Farm.

Final conclusion: While many of the conclusions of the BCRET report are poorly conceived or inadequately supported, we believe that BCRET has conclusively found at least two smoking guns: the operations and actions of C&H Farm consistently produced a doubling of nitrate surface water concentrations over the 2.5 mile stretch that Big Creek flows adjacent to the farm and the ever increasing nitrate levels in the house well and Ephemeral Stream. It is unfortunate that this farm was ever permitted to be sited in the Buffalo National River watershed. Adding insult to injury, it was allowed to operate in such a way that it contaminated Big Creek. We hope that ADEQ will permanently protect the Buffalo National River from the likes of medium and large swine CAFOs and prevent another future 6 million dollar (and counting!) mistake like the buyout, closing, and cleanup.

David Peterson, President, Ozark Society, retired mathematician
Alan Nye, Ozark Society board member, retired toxicologist

Muddy water from Big Creek enters the Buffalo River at Carver – Photo, Carol Bitting