Marilyn Kreps

Attached are the Comments of the Ozark Society concerning C&H Hog Farms, Inc.'s permit denial.

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October 16, 2018

Via Email Water-Draft-Permit-Comment@adeq.state.ar.us

Arkansas Department of Environmental Quality
ATTN: C&H Draft Denial
5301 Northshore Drive
North Little Rock, Arkansas 72118-5317

Re: Draft Denial of Liquid Animal Waste Management System Permit
Applicant: C&H Hog Farms, Inc., HC 72 Box 2
Vendor, AR 72683
Permit Number 5264-W; AFIN 51-00164

Dear Sir or Madam:

I represent the Ozark Society, Inc., Dr. Alan Nye, Dr. David Peterson and Robert Cross. The Ozark Society is a non-profit corporation formed pursuant to the laws of Arkansas. The attached comments (Attachment "1") in support of ADEQ's decision to deny the permit application of C&H Hog Farms, Inc. are submitted on behalf of the Ozark Society, Dr. Alan Nye, Dr. David Peterson and Robert Cross (referred to as the Ozark Society commenters). We support ADEQ's proposal to deny a permit that would allow C&H Hog Farms, Inc. to operate a large CAFO near the Buffalo River in perpetuity.

The Ozark Society was founded in 1962 by Dr. Neil Compton of Bentonville and a group of associates for the immediate purpose of saving the Buffalo River from dams proposed by the U.S. Army Corps of Engineers. Society founders, working with elected officials, helped get the National Park Service to survey the Buffalo River area and then began to campaign for the creation of the "Buffalo National River" as an alternative to the dams. It took ten years, but Congress passed legislation to create our nation's first "national river" in 1972 and it is now one of mid-America's most outstanding river-oriented attractions. Since its designation as a National River, the Ozark Society has worked to preserve its pristine water quality and wild and scenic nature from all threats: agricultural and human waste, unneeded or poorly designed road building, haze, odors, and other air quality issues, fracking intrusion, overdevelopment and over use in the park itself. The Ozark Society has a three-fold mission of conservation, education, and recreation. The Ozark Society has approximately 1,008 dues paying members, approximately 80% of whom are from Arkansas. Members of the Ozark Society enjoy all forms of recreation allowed on the Buffalo River.

Dr. Alan Nye is a toxicologist who resides at 12 Platte Drive, Maumelle, AR 72113. His telephone number is 501-258-7137. Dr. Nye is an adjunct faculty member of the UAMS Fay W. Boozman College of Public Health. Dr. Nye has been a member of the Ozark Society for over 30 years and is immediate past president of the Ozark Society. Dr. Nye and his wife own a residence in Gilbert, Arkansas (61 Frost Street, Gilbert, AR 72636) near the Buffalo River. Dr. Nye has canoed the Buffalo River on many single-day and multi-day trips with his family and friends since the late 1980s, and has also day hiked and backpacked many times on the Buffalo River Trail. Dr. Nye enjoys and seeks to preserve the unique characteristics of the Buffalo River, including recreational and aesthetic values associated with this Outstanding National Resource Water. Water quality of the Buffalo River is of paramount importance to Dr. Nye.

Robert Cross is an Emeritus Professor of Chemical Engineering at the University of Arkansas in Fayetteville. He resides at 315 N. Fletcher Ave. in Fayetteville, AR 72701 and his telephone number is 479-466-3077. He was previously a Research Professor of Chemical Engineering at the UofA and before that was the President and Technical Director for many years of Romicon, Inc., a subsidiary of the Rohm and Haas Co., located in Boston. He was involved in the development, manufacture, and sale of advanced separations equipment including membrane technology for water and waste treatment. He is currently working on the development of more economical and reliable process to produce drinking water for households in third-world countries. His education includes a B.S.Ch.E. from the UofA and a M.S.Ch.E. from M.I.T. He has been a member of the Ozark Society for 20 years and has served as Vice President for six years and President for six years. He is currently a State Director for Arkansas. He has hiked for many years in the Buffalo Nation River as well as the Upper and Lower Buffalo National Wilderness and has canoed most sections of the Buffalo River.

Dr. David Peterson is a retired math professor from UCA, who lives at 56 Ridge Drive, Greenbrier, AR 72058. His telephone number is 501-679-2935. He and his family have been involved with the Ozark Society since 1978. Dr. Peterson is the immediate past president of the Pulaski Chapter of the Ozark Society and currently is president of the Ozark Society. He and his wife Donna have hiked and canoed the entire length of the Buffalo River, and explored many tributaries as well. As an avid fisherman, Dr. Peterson admires the native smallmouth bass in the watershed and realizes that water quality is paramount in preserving this resource. Given his avocation as a statistician, he has spent many hours modeling nutrient flow in the Buffalo River, its tributaries, and Big Creek in particular.

In support of permit denial, we adopt and incorporate by reference the entire record before ADEQ on this matter that is viewed at the following link:

https://www.adeq.state.ar.us/home/pdssql/p_permit_details_water_spb.aspx?AFINDash=51-00164&AFIN=5100164&PmtNbr=5264-W). This includes, without limitation:

Public comment submitted during the previous public comment period on this permit application, including comments of the Ozark Society, Robert Cross, David Peterson and Alan Nye submitted in opposition to ADEQ's initial permitting decision dated April 6, 2017, the Buffalo River Watershed Alliance, the Arkansas Canoe Club, Gordon Watkins and Marti Olesen;

Expert reports in connection with C&H's permit appeal (18-001-P):

Thomas Aley dated May 29, 2018;

James C. Petersen dated May 31, 2018 and revised October 15, 2018 (Attachment "2" hereto);

Dr. Lee J. Florea, P.G. dated June 4, 2018;

Dr. Michael Smolen dated June 1, 2018;

Dr. J. Berton Fisher dated May 27, 2018;

Robert Cross; and

David Mott;

All deposition testimony taken in connection with C&H's earlier permit appeal (18-001-P) including, without limitation:

Deposition of Dr. Andrew Sharpley;

Deposition of Jason Henson;

Deposition of Tana Henson;

Deposition of Monica Hancock;

Deposition of Dr. Robert Blanz; and

Deposition of Dr. Jamal Solaimanian;

Subpoena to Dr. Andrew Sharpley and Response thereto;

Materials contained in Docket No. 18-001-P; and

BCRET reports and the "Expert Panel" Report dated May 19, 2014.

In addition to the comments we are submitting, we adopt by reference, as if stated word for word herein, all other comments submitted in support of permit denial, including, without limitation, comments submitted by the Buffalo River Watershed Alliance, the Arkansas Canoe Club, or its members.

For the reasons set forth in our comments and others supporting permit denial, we respectfully request that ADEQ deny the permit.

Thank you.

Sincerely,

Samuel E. Ledbetter

SEL/

Enc.

Attachment "1" – Detailed comments of the Ozark Society concerning ADEQ's public notice to deny a Regulation No. 5 (Reg. 5) "no discharge" permit for C&H Hog Farms (C&H)

These comments are submitted on behalf of the Ozark Society, Dr. David Peterson, Robert Cross and Dr. Alan Nye (hereafter "OS") in response to Arkansas Department of Environmental Quality's (ADEQ) September 2018 Statement of Basis for its decision to deny the application of C&H for a Reg. 5 permit.

Permit History/Activity. On April 6, 2017, OS submitted comments to ADEQ during the initial public comment period for draft permit 5264-W (hereafter referred to as "OS 2017 p. ___"). Those comments urged denial of draft permit 5264-W and address C&H's Reg. 5 permit application and accompanying material contained in the permitting record at that time. Those comments are incorporated by reference herein as if repeated word for word. In addition to commenting on the earlier draft permit decision in support of permit denial, OS intervened in C&H's appeal of ADEQ's January 10, 2018 permit denial. OS has sought to intervene in an appeal related to coverage under C&H's expired Regulation 6 General Permit. These comments focus on the Statement of Basis (SOB) dated September 17, 2018, as well as new information since our earlier comments of April 6, 2017, including without limitation, the record developed in connection with Docket No. 18-001-P and materials contained on ADEQ's website under 5264-W titled "Additional Information 5264-W," which is adopted by reference and incorporated in our comments to the extent it provides additional support for permit denial. *See*, https://www.adeq.state.ar.us/home/pdssql/p-additional-information-5264-w.aspx

Facility Location. C&H is located on the karstic Boone Formation less than 5-miles from Buffalo National River. C&H should never have been authorized to construct and operate a Liquid Animal Waste Management System (also known as an Animal Waste Management System or AWMS) to dispose of waste from a large swine Concentrated Animal Feeding Operation (CAFO) at this location. The hydrogeologic properties of the karst aquifers in the Buffalo River watershed and the state and national significance of the Buffalo River combine to create a valuable Arkansas resource very susceptible to the contaminants in swine manure. The Buffalo River is unique, possessing a combination of attributes unmatched in our state, and arguably the nation:

- The Buffalo River has both Extraordinary Resource Waters (ERW) and Natural and Scenic Waterways (NSW) designations under Clean Water Act and State regulations.
- The Buffalo River is the primary natural resource and recreational element of the Buffalo National River - America's first National River.
- The watershed contributing flow to the Buffalo River is mostly underlain by karst.
- The Buffalo National River is one of Arkansas's tourism hotspots, with over a million visitors per year coming to experience the clean, clear waters of a large karst river.
- Numerous dye tracing studies have shown the complicated and rapid transport of groundwater through the region's karst drainage networks.

For these general reasons and the specific reasons listed in the following comments and references herein, C&H should not receive a permit. Any large swine CAFO constructed in the Buffalo River watershed, on karst, and on a major tributary to a National River, must be held to higher environmental standards than a facility built in an area characterized by rich homogenous soils and non-karst geology. There are literally thousands of suitable locations in Arkansas where the downstream receiving water is not a crystal clear karst river of national significance, critical to the local tourism economy, and susceptible to nuisance algae blooms.

Given the location of this CAFO, it is reasonable to expect that:

1) A professional geologist would be involved with the planning and design of such a facility, although none was;

2) The design engineers would closely examine and account for the karst geology and yet the presence of karst is not mentioned in the application;

3) The applicant would collect and analyze technical information required by Regulation 5 and the Agricultural Waste Management Field Handbook (AWMFH), but again this didn't happen; and

4) There would be an independent review and assessment of all the required data and facts, and yet there wasn't.

We submit that a qualified team of planners utilizing appropriate guidance would conclude the present location next to Big Creek is a poor/unsuitable location for a large AWMS and explain this fact to a reasonable operator in the first planning meeting. The AWMFH states "Location of a facility is an extremely important consideration during the planning process to minimize exposure to vulnerability and risk." AWMFH 651.1000 (4). This CAFO should never have been built in its current location and is only there because of a failure to properly assess site-specific concerns in the original "general" permitting process.

Waterbody Evaluation. This section of the SOB states "Surrounding areas were evaluated to determine if any Extraordinary Resource Waters (ERWs), Natural or Scenic Waterways (NSWs), or waterbodies in the 2016 or the proposed 2018 list of impaired waterbodies in the State of Arkansas are near the proposed land application sites." While the ensuing discussion focuses on impairment of both Big Creek and the Buffalo River, it fails to mention that the Buffalo River is designated as both an ERW and NSW. OS 2017 p. 7 discusses the need to recognize the resource sensitivity of the area and make the potential impacts to the existing water quality of the Buffalo River part of the design considerations and permit review. C&H is contributing nutrients, bacteria and suspended solids to the Buffalo River, as documented in the previous comments and references contained therein, the expert reports/opinions, and deposition testimony taken in connection with permit appeal 18-001-P, and the recent impairment designations. Data collected since the beginning of operations at C&H shows water quality impairment exceeding Arkansas's water quality criteria. By definition, the existing water quality of the Buffalo River is not being maintained, and this facility is causing or contributing to water quality degradation in an Outstanding National Resource Water (ONRW) in violation of the

Clean Water Act and the AWMFH. Reg. 2.203 states "Where high quality waters constitute an outstanding state or national resource, such as those waters designated as Extraordinary Resource Waters, Ecologically Sensitive Waterbodies or Natural and Scenic Waterways, those uses and water quality for which the outstanding waterbody was designated shall be protected by (1) water quality controls, (2) maintenance of natural flow regime, (3) protection of instream habitat, and (4) encouragement of land management practices protective of the watershed.

OS supports ADEQ's decision to list Big Creek and the Buffalo River as impaired and to associate these impairments to recent animal waste disposal activities at C&H. Our previous comments note both the elevated pathogen levels in Big Creek and the Buffalo River, and the dissolved oxygen water quality violations at the USGS sampling station at Big Creek near Carver (OS 2017 p. 13 and 14). Granting a permit to C&H would violate 2.203 by continuing to allow water quality to decline, constituting a land management practice that is not protective of the watershed.

Big Creek at Carver is within ½ mile of the confluence of Big Creek and the Buffalo River. Within the Buffalo River channel downstream from this confluence is a large spring identified by a USGS flow gain and loss study discussed in detail in Aley 2018. It is very likely that groundwater discharged from the Big Creek aquifer flows directly to the Buffalo River. This location presents complex challenges. The minimal engineering protections that characterize the planning, design, construction and operation of this CAFO under the expired general permit (which were performed by a firm from North Dakota lacking appropriate knowledge and expertise) is unacceptable.

Big Creek Research Extension Team (BCRET) sampling has identified statistically significant increases in nutrient concentrations in the local aquifer and in surface water during base flow conditions. However, BCRET sampling is neither designed nor conducted in a manner that provides quantitative storm loading estimates. In his deposition, Dr. Sharpley (p. 13 – 14; found at https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Deposition%20Sharpley%20with%20Exhibits.pdf) stated that he does not consider himself an expert in karst hydrology and has never designed, conducted, or led any similar watershed-scale water quality study. Previous studies (as referenced in the OS's previous comments and the expert reports prepared on our behalf as well as on behalf of Buffalo River Watershed Alliance (BRWA)) show that swine CAFOs such as C&H are a major contributor to nutrient loads in receiving streams and these loads are dominantly transported during storm events. Dr. Sharpley also testified (p. 42) "If we were concerned with fluxes in terms of amounts of nutrients coming out, we would be concerned with high flows." Storm event water quality conditions and loads remain unassessed, but the weight of the evidence supports our position that the ONRW designation and accompanying antidegradation policy are being violated by runoff and groundwater inputs related to the operation of C&H's liquid animal waste disposal system. This point is discussed and detailed below.

Applicant Activity – The applicant's activity should be placed in a more representative context. For example, this facility is categorized as a large swine CAFO under CWA definitions and is the largest CAFO ever constructed and operated in the Buffalo River watershed. It is located in a karst landscape in a sensitive area. This type and size of facility has long been a source of environmental concern, leading ADEQ in 1992 to place a moratorium on Regulation 5 permits in the Buffalo River watershed (OS 2017 p. 57 – 59). This application must be reviewed with the potential impacts to the Buffalo River and its ONRW values as a primary concern. The applicant fails to demonstrate that it understands the hydrologic and socio-economic consequences of its actions or that it has devised acceptable strategies to avoid measurable contamination of Waters of the State, first and foremost being the Buffalo River.

Facility Type and Size

C&H's permit application seeks to increase the number of swine from 6,503 to 6,878. Reg. 5.901(D) prohibits an increase in the number of swine at this facility. Three hundred and seventy five swine may not seem like a lot, but that is the size of the typical permitted hog farm in the Buffalo River watershed prior to the construction of C&H. Even a 300 to 400 sow facility can cause measurable water quality degradation as evidenced by the 1992 ADEQ moratorium on Regulation 5 permits in the Buffalo River watershed. As an additional basis for permit denial please see OS 2017 p. 55 – 56. This issue is discussed below under the "Additional Bases for Denial."

Basis for Permit Decision

The OS concurs with ADEQ's denial decision and its determination that the record lacks necessary and critical information to support granting a permit and contains information that the operation of this facility may not only be affecting water quality in the area, but also contributing to water quality impairments in Big Creek and the Buffalo River. We also offer additional Bases for Denial items:

1. **C&H has not evaluated, designed, constructed or operated in compliance with Reg. 5.102 and Reg. 5.402**
2. **C&H is discharging to waters of the State in violation of 5.102.**
3. **C&H is contributing to declining water quality in the Buffalo River in violation of Regulation No. 2, the Clean Water Act (see APC&EC Reg. 2, Chapter 2: the Clean Water Act § 303 (33 U.S.C. § 1313) and 40 CFR § 131.12), and AWMFH 651.0202 C (17).**
4. **The number of swine at the facility has increased in violation of the 2016 APC&EC moratorium Reg. 5.901(D).**

OS 2017 listed many of the information shortcomings of C&H's Reg. 5 application and established that the application, as stated in the SOB, lacked the "necessary and critical information to support granting of the permit, and the record contains information that the operation of this facility may be contributing to water quality impairments of water of the state." This prevents ADEQ from evaluating the permit under both Reg. 5.102 and 5.402 (OS 2017 p. 18 – 55). In connection with C&H's appeal of ADEQ's earlier denial, we engaged Mr. Tom Aley to review the permit application, environmental setting, and compare the geotechnical requirements of the AWMFH to the information provided by the applicant. See, https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Expert%20Report%20Aley.pdf (hereafter referred to as Aley 2018)

Mr. Aley's opinions include:

- C&H is sited on the karstic Boone Formation
- The Boone Formation has a high infiltration rate and the Arkansas Phosphorus Index does not account for nutrient transport to groundwater
- Polluted groundwater from C&H could migrate directly through the karst groundwater network to the Buffalo River
- The permit application fails to provide the requisite technical information or a credible explanation of how operation of C&H will be able to comply with Reg. 5.406 (C) in this sensitive location
- The waste storage ponds and their clay liners are inadequate for waste storage in karst

In support of denial, OS adopts and incorporates herein by reference Mr. Aley's report and the opinions contained therein. OS also engaged Dr. Lee Florea, a hydrogeologist and member of the expert panel that reviewed the BCRET study. Dr. Florea has visited the area to review karst water quality related concerns. His opinions reinforce those expressed by Aley. *See*, https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Expert%20Report%20Florea.pdf hereafter referred to as Florea 2018. Dr. Florea's opinions are incorporated herein in support of permit denial.

In its 2017 comments, the OS presented detailed discussions of water quality concerns which are summarized as follows:

- Waste holding ponds are leaking to groundwater and the actual leakage rate has not been determined even though this is a simple process.
- Waste holding ponds are constructed on karst and the bottom of the ponds are likely constructed within the epikarst zone.
- Excess phosphorus is accumulating in application fields. A legacy phosphorus situation is developing.
- The Buffalo River is susceptible to nuisance algae blooms and C&H produces, stores, and surface applies a large amount of the nutrients that drive these algae blooms.
- Downstream sampling of Big Creek shows elevated nutrients, chloride, total suspended solids, and total coliform bacteria compared to the upstream site.
- More nitrogen and phosphorus is being imported into the Big Creek watershed by C&H than is being exported in agricultural products. Most of the surplus nutrients are eventually transported to surface and groundwater.
- There is no credible water quality baseline representing pre-C&H conditions.
- Buffalo River water quality is degrading as a result of increased agricultural activity in the watershed and C&H is contributing to this water quality decline.
- Water quality declines are a violation of the ONRW status and the designated uses applicable to ERW and NSW waters.

- Primary transport of nutrients, pathogens, and other contaminants of concern from C&H to the Buffalo River remains unquantified. 80 to 90 percent of this transport occurs during storm runoff conditions. The BCRET study lacks the necessary design and implementation measures required to assess, quantify and compare storm loading.
- The BCRET "study" is poorly designed and implemented. The BCRET "Team Leader" (Dr. Sharpley) inaccurately represents BCRET's findings and results in a number of respects. Dr. Sharpley is not an expert in the fields of hydrogeology, watershed science, and in-stream water quality data collection and analysis. While there may be members of BCRET who could offer expert opinions in these areas, Dr. Sharpley cannot. Moreover, the BCRET study, results and findings have not been peer reviewed. OS submits that BCRET's work would not withstand peer review due to numerous flaws, including, without limitation, data gaps, flaws in QA/QC, data collection and analysis protocols (or lack thereof) that render the study unreliable.
- Dye-tracing to date indicates groundwater moves great distances at high rates of speed and may be discharging directly to Buffalo National River's springs and streams.
- USGS continuously recording nitrate sensor at Carver shows slugs of nitrate moving into the Buffalo River in conjunction with storm events. Time of travel estimates place the source of these slugs upstream at a distance consistent with the distance from C&H to the Carver sensor. Based on literature and previous studies, total nitrogen and phosphorus, sediment, pathogens, and other constituents of concern are likely being loaded into the Buffalo River at even greater magnitude than shown for nitrate.
- BCRET field flumes show runoff from C&H is much higher in phosphorus and nitrogen then the receiving stream, Big Creek, and that much of the phosphorus is in dissolved form and immediately available for plant stimulation.
- Bacteria levels often exceed state numeric water quality standards in both Big Creek and the Buffalo River.
- BCRET data is only useful in characterizing base flow water quality conditions. Within the BCRET database, flags characterizing samples as base flow or storm flow are often wrong.
- BCRET has no discharge data for the upstream site, therefore accurate flux and load comparisons between the upstream and downstream sites cannot be made. Seasonal and annual stream loads contributed by C&H cannot be accurately calculated.
- BCRET uses automated samplers in an effort to collect storm runoff samples. However, their operational design and implementation lacks any pre-planning or quality control documentation. This method has failed to capture the vast majority of storm flow events and for those events it has captured, critical data needed to assess storm flows is missing or not gathered. The data collected by these automated samplers has not been interpreted or subjected to peer review. As such, storm flow data critical to understanding the impact C&H is having on the receiving stream, is not available.
- Trends in nitrate and total nitrogen appear to be increasing with time downstream of C&H but not upstream.

- USGS dissolved oxygen data from Carver clearly shows water quality numeric criteria are being violated.
- Nitrate values are significantly elevated in groundwater near C&H as compared to Big Creek. Groundwater is being loaded with nitrate and discharging via the karst drainage network to Big Creek and the Buffalo River.
- A large spring is located in the channel of the Buffalo River downstream from the confluence of Big Creek. This spring could be a direct conduit for groundwater flow from the Big Creek basin to the Buffalo River.
- Soil phosphorus levels are high and increasing in most of the spreading fields leading to elevated phosphorus in runoff waters and a legacy phosphorus situation is developing.
- Soil type, characteristics, and thickness in the area are mostly inadequate to provide the waste assimilation capacity mandated in the AWMFH.
- High nitrate values were detected in the BCRET monitored spring, house barn well, and trenches and OS recommended a trend analysis be performed on these data.
- The increased levels of nutrients in surface and groundwater near C&H, and in the Big Creek valley below C&H, are causing low dissolved oxygen values at Carver.
- Increasing nutrient levels transported from C&H spreading fields to the Buffalo River is likely contributing to nuisance algae blooms in the Buffalo River.
- Water quality deterioration in the Buffalo River (as well as the perception of the public regarding risks associated with primary contact in the river this CAFO has created) threatens the tourism economy in the area.
- The AWMFH requires application of nutrients at levels that match plant needs, and in a resource sensitive area such as this, to apply only at agronomic rates, not at rates that result in use of soils as phosphorus disposal sites.
- Waste application rates are "haphazard" and the actual nutrient application rates at C&H may be far different from the recommendations (guestimates) in the Nutrient Management Plan.
- C&H is not following Dr. Sharpley's (or the AWMFH's) recommendations for storage pond management or waste spreading.
- C&H has not implemented any of Dr. Sharpley's recommendations to modify the waste stream to remove excess phosphorus and/or improve the ratio of nitrogen and phosphorus in the applied waste.
- Applying the lessons ADEQ learned from studies conducted in response to the 1992 moratorium on swine CAFOs in the Buffalo River Watershed supports permit denial.
- As soil phosphorus levels increase, so do levels of phosphorus in surface and groundwater leaving the field.
- BCRET mostly ignored the review comments of the expert team sent to evaluate its work. Even a simple gain and loss study to understand the basics of karst groundwater/surface water interactions has not been conducted.
- A number of significant problems with the BCRET study were identified by the expert panel. In summary the BCRET study fails to meet the design and QA/QC requirements

necessary for the collection of meaningful and accurate data that allows for a complete interpretation of impacts.

- Dye tracing indicated the upstream "control" site may also be receiving recharge from application fields located in the Dry Creek basin.
- Waste application records indicate waste is not being spread evenly or consistently on application fields.

The Buffalo River and Big Creek have recently been designated impaired under the Clean Water Act. Permitting the largest swine CAFO in the entire Buffalo River watershed would continue to exacerbate this impairment. In OS 2017 p. 14 – 17, we noted that data collected by the USGS at Carver reflected that Big Creek was not meeting State standards for dissolved oxygen. The violation of State water quality standards due to low dissolved oxygen values is most probably due to nutrient eutrophication and/or assimilation processes taking place in lower Big Creek. It is a fact that C&H is the largest generator of nutrients in the Big Creek watershed (in fact it is the largest generator of nutrients in the entire Buffalo River watershed).

Deficiencies in the Geological Investigation:

The OS concurs with ADEQ's determination that C&H is located on karst, a fact that cannot be disputed and which is supported by Dr. Sharpley and his collaborators (Sharpley deposition p. 90). The statements made by Terracon and Carmen demonstrate they are at best uninformed and at worse biased and thus these statements cannot be given credibility. In the SOB, ADEQ acknowledges that this facility is "located in a sensitive geologic area." SOB p. 4. ADEQ further acknowledges that this permit must be evaluated based on site-specific conditions and in full compliance with the AWMFH.

The SOB refers to and discusses 651.0503 and 651.0504 of the AWMFH, and reviews the recommended methods for determining soil suitability for waste application. Highly permeable soils, often thin and overlying karst formations in the watershed of Buffalo National River by definition are in the "severe" limitation category. The AWMFH requires a careful and comprehensive examination of soil and numerous other site conditions and the AWMFH supports ADEQ in that "The presence of karst triggers additional considerations for siting and design. An example of how this AWMS would have to be redesigned to comply with the AWMFH concerns waste application rates. In sensitive areas, the AWMFH cautions against using manure management planning such as provided by the Arkansas Phosphorus Index (API) which is the equivalent to Strategy 2 listed below (651.1105(c)).

> Two strategies can be used for manure utilization: management for maximum nutrient efficiency, and management for maximum application rate of manure.
>
> **Strategy 1 —Management for maximum nutrient efficiency.** This strategy best realizes the value of the nutrients in the manure. The rate of application is based on the nutrient available at the highest level to meet the crop's needs. This element is often phosphorus. The manure rate is calculated to meet the requirement of phosphorus, and additional amounts of nitrogen and potassium are added from other sources (generally commercial fertilizers). This rate is most conservative and requires the greater

supplement of fertilizer, but applies nutrients in the quantities that do not exceed the recommended rates for the crop.

Strategy 2—Management for maximum application rate of manure. This is the strategy employed when the land available for application is limited, and it fails to fully realize the value of the nutrients in the manure. The most abundant element in the manure, generally nitrogen, is used to the greatest extent possible. The manure rate is calculated to meet the nitrogen need of the crop. Often the crop is chosen to maximize the nitrogen uptake. This maximizes the application rate of manure, but will overapply phosphorus and potassium for the crop's requirement. **Over the long term, this will lead to an undesirable accumulation of phosphorus in the soil. Once a phosphorus threshold is reached, another strategy will need to be employed and manure will need to be applied elsewhere.** (emphasis added)

C&H's use of the API (Strategy 2) application rates is causing phosphorous concentrations to increase in the C&H waste application fields as noted in previous comments, by Dr. Sharpley in his deposition, and now by ADEQ. Use of the API does not account for karst as stated by Dr. Sharpley (deposition p. 18), and in fact the API does not even consider infiltration of nutrients to groundwater. Aley opines that on average 65 percent of the water delivered to the Buffalo River from karst areas of the watershed travels through the karst groundwater network (Aley 2018). In his deposition at p. 90, Dr. Sharpley agreed that infiltration can be the dominant pathway for nutrients to enter karst. The use of the API to calculate waste application rates to develop the NMP for C&H is causing groundwater contamination with nitrate and elevated nitrogen and phosphorus in soils and surface runoff. Dr. Sharpley agreed in his deposition that testing results indicate a legacy phosphorus condition is developing at the C&H fields he monitors (p.183). This location is not appropriate for a large CAFO no matter how it is designed. The obvious cost-effective and environmentally responsible alternative is to locate such operations in a setting more consistent with the recommendations of the AWMFH.

Karst is given particular attention in the AWMFH. Discussions of karst issues are in comments submitted in the previous public comment period. We have supplemented the record with additional expert opinions. Karst issues were ignored in the Reg. 5 permit application. The Dr. Florea provides two pertinent examples of cases where failing to plan karst complexity yielded negative environmental consequences (Florea 2018). All C&H buildings and waste storage ponds, and all of the land application fields except for part of Field 17 and a very small part of Field 4, are underlain by the Boone Formation. In a number of the land application fields the Boone Formation is overlain by a veneer of highly permeable alluvium. The Boone Formation is a major karst aquifer in Arkansas, Missouri, and Oklahoma (see OS 2017; Aley 2018, p 7 – 24; and Florea 2018 for a detailed and accurate description of the OS's concerns related to the region's karst hydrogeology).

The SOB correctly states "The presence of karst triggers additional considerations for siting and design as stated in the...AWMFH." There are additional issues presented by the presence of karst as discussed in the AWMFH. An entire chapter of the handbook is titled "Geologic and Groundwater Considerations", and karst is discussed repeatedly as a major design and operational concern. While concerns about catastrophic events, such as in the example text cited in the SOB, are valid and fully supported by OS, probable water contamination is the dominant theme of the AWMFH's discussion of karst. OS 2017 p. 36 – 55 discusses karst concerns as presented in the AWMFH and applicable to C&H Hog Farms:

- A detailed planning and analysis of the AWMS has not been conducted. If the information submitted with the permit application is to be considered C&H's AWMS plan, it lacks many important considerations defined in the AWMFH.
- A NRCS Conservation Plan is required and has not been developed.
- A "complete systems approach" was not followed and this led to numerous incorrect decisions including the ongoing disposal of excess phosphorus in soils.
- The AWMS must be designed with maintenance or improvement of surface and ground water quality as a priority.
- Alternative construction and operation scenarios have not been developed for the AWMS. Specific measures to reduce contaminated runoff and infiltration in a karst landscape have not been assessed.
- The required site evaluation criteria have not been collected or analyzed, including the many sources of data and information that have become available since operation commenced.
- Appropriate experts such as geologists, water quality specialists, and NRCS staff, were not utilized in planning and construction.
- The original NOI and construction planning documents did not include a recognition or assessment of the area's karst geology or its karst aquifer. The result is a facility design not compatible with the AWMFH.
- The use of waste storage ponds with synthetic or clay liners is not allowed in karst settings in recognition of numerous commonly acknowledged risks such as leaching or soil piping through the clay liner, rips and tears in a synthetic liner, and subsequent risk to water quality and the potential for catastrophic failure.
- The disposal of nutrients from the swine wastes to waste application fields at rates that exceed plant uptake and soil test-based agronomic recommendations is not justified for sensitive areas such as karst near Buffalo National River.
- The firm that prepared the original Notice of Intent (NOI) did not assemble the team of professionals required. It did not involve a geologist or geohydrologist, a water quality specialist, or NRCS specialists. In fact, the original NOI developers were located in North Dakota, and did not even mention the site's karst geology or its proximity to the Buffalo River.
- Topography includes karst and since the Arkansas Geological Survey Map for the Mt. Judea area shows Boone Formation underlying the C&H's waste application fields, karst is undoubtedly present as the top layer of the bedrock. As outlined above in Chapter 5(d), the depth to bedrock should be determined for each waste application field as well as for the pond area. The "Topography" section on page 7-14 discusses the importance of mapping the karst terrain. For the waste application fields this may require test pits and/or ground penetrating radar and the services of a geologist. The karst as the top layer of the bedrock in areas of shallow soil may rule out some waste application fields or areas of some waste application fields for use. Quoting from the AWMFH:

> "When designing any agricultural waste management component, it is important to know what type(s) of aquifers are present and at what depth"
>
> **"Sinkholes or caves in karst topography** or underground mines **may disqualify a site for a waste storage pond or treatment lagoon.** Sinkholes can also be caused by dissolving salt domes in coastal areas. The physical hazard of ground collapse and the potential for groundwater contamination through the large voids are severe limitations…"
>
> "Karst topography is formed on limestone, gypsum, or similar rocks by dissolution and is characterized by sinkholes, caves, and underground drainage. Common problems associated with karst terrain include highly permeable foundations and the associated potential for groundwater contamination, and sinkholes can open up with collapsing ground. **As such, its recognition is important in determining potential siting problems."** (Emphasis added)."

- Table 10-4 categorizes C&H as an AWMS that meets the "very high vulnerability" criteria and requires the planner to "Evaluate Other Storage Alternatives" because of the karst geology and associated ground water contamination, leakage, and collapse potential. The "Other Storage Alternatives" include all alternatives with the exception of storage ponds with synthetic or clay liners.
- The choice of a waste storage system must also consider potential waste treatment options. The planner is to develop waste treatment options based on "a total system design" which properly accounts for the karst environment, soil and waste nutrient levels, and environmental sensitivity.

OS 2017 p. 36 – 55 describes the lack of any geological investigation of this facility. Dr. Blanz's deposition (at p. 20) establishes that it is the applicant's responsibility to submit the appropriate information to support permitting decisions. (https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Deposition% 20Blanz%20with%20Exhibits.pdf). The three borings used to characterize the soils near the barns and storage ponds **do not** even meet the minimum of six borings as required in the AWMFH (regardless of site sensitivity) for this specific data collection activity. The AWMFH also lists many other data collection (and analysis by a qualified specialist) requirements which have not been conducted. Mr. Aley's evaluation supports ADEQ's conclusion that the applicant has failed to submit the type of geotechnical information required, and thus, beyond the lack of required information, there is nothing to comment on.

We agree with ADEQ's concerns that both the physical properties and thicknesses of the soils in the land application sites are insufficient to assimilate large volumes of swine waste in this karst setting, and that the application rate is excessive given the ease with which karst ground water and surface runoff can become contaminated. The last paragraph of this section is critically important and makes it clear ADEQ recognizes the need to use relevant site-specific data and engineering to redesign this facility and revise operations to comply with the AWMFH. The OS agrees that "The ultimate aim of APC&EC Reg. 5 and the AWMFH is that pollutants are not being released from the facility to waters of the state." SOB p. 7.

Water Quality Issues:

Our 2017 comments presented detailed assessments of water quality conditions and conclude that pollutants are being released from C&H to aquifers, karst drainage networks, Big Creek and the Buffalo River. A summary of our findings was presented earlier. Since April of 2017, more information has emerged supporting this conclusion. We engaged Mr. James C. Petersen to analyze and interpret the water quality data collected by BCRET. Mr. Petersen is a respected expert whose career with the USGS in Arkansas includes work in the fields of water quality and aquatic biology in Ozark streams.

Mr. Petersen's revised report accompanies these comments. It is adopted by reference and incorporated herein and referred to as "Petersen 2018." His major points are:

- The waste storage ponds are leaking to groundwater which eventually discharges to surface water and private wells. Nitrate levels, along with other parameters, are increasing in the well and ephemeral stream near the waste storage ponds. The monitored trenches below the ponds show evidence of contamination, and the Harbor Drilling study showed anomalously high phosphorus levels in the aquifer below the ponds.
- Nitrate, total nitrogen, dissolved phosphorus, and chloride levels are increasing downstream of C&H but not upstream.
- BCRET data are not sufficient to generate annual or seasonal load estimates, a major shortcoming of the study but only one of many shortcomings pointed out by the expert review panel.
- Aquatic communities are being impacted by high nutrient levels and low dissolved oxygen.

The OS also concurs with ADEQ's concerns regarding soil phosphorus build up at the already high in phosphorus land application sites. BCRET's Dr. Sharpley has researched the effects of phosphorous build up in soils and employs the term "legacy P." A legacy P problem should not be the goal of nutrient management planning efforts. Waste management for a large CAFO generating millions of gallons of swine waste every year is a tremendous responsibility. Waste storage, removal, agitation, sludge management, application, testing and disposal operations should be aligned to a plant utilization model of nutrient management, as clearly required by the AWMFH. Phosphorus should not be allowed to build in soils until it exceeds the agronomic needs of the crops because both runoff and infiltration concentrations of nutrients increase as soil test phosphorus levels increase. Dr. Sharpley has shown how long-term buildup of phosphorus in soils can lead to legacy phosphorus conditions, as is currently taking place on most C&H waste application fields (Sharpley deposition p. 183). These conditions may take decades (perhaps as long as a century) to correct. Our previous comments regarding C&H's waste management, soils, and phosphorus remain valid and can be found at OS 2017 p. 21 – 29. Our analysis of geotechnical assessment requirements and AWMFH guidelines for soils can be found at OS 2017 p. 40, 44 – 47 and at Aley 2018 p. 19, 26-27, 33-36.

In its SOB, ADEQ states that it needs "C&H to provide the appropriate geotechnical data to demonstrate this facility has been constructed in accordance with the AWMFH." Appropriate geotechnical data is only the first step in assessing and designing an AWMS. The AWMFH requires the geotechnical data to be collected and analyzed by appropriate professionals and used in the design, construction and permitting process so that ultimately an AWMS can be located, assessed, designed, constructed and operated in an environmentally sound manner (a manner consistent with Reg. 5). This facility was not designed and constructed in compliance with the AWMFH. Pollutants are being discharged from the AWMS to waters of the State. C&H's permit application must be denied because this facility is designed to discharge to waters of the state and is not in compliance with the AWMFH - primarily because there are no modifications that reflect the karst terrain the facility is sited on, nor the sensitive resource concerns associated with receiving waters such as those within Buffalo National River.

Finally, the OS offers the following four comments as additional reasons for denial:

1. C&H Hog Farms not evaluated, designed, constructed or operated in compliance with Reg. 5.102 and Reg. 5.402

Reg. 5.102 states:

> The purpose of this regulation is to establish **minimum** qualifications, standards and procedures for issuance of permits for confined animal operations using liquid animal waste management systems within the state and for the issuance of permits for land application sites within the state. (Emphasis added).

Thus, the regulation contemplates more stringent "qualifications, standards and procedures for issuance of [CAFO] permits" where circumstances require them. This is consistent with other guidance for siting large swine CAFO's and with our position that there are certain areas in the State where large swine CAFOs should not be sited. The C&H CAFO generates more than three times as much phosphorous as the entire human population of Newton County, is the largest CAFO in the Buffalo River Watershed, and is located in an area of karst geology less than 5 stream miles upstream of the Buffalo National River, America's First National River and perhaps the most important tourism destination in Arkansas. Yet, the qualifications, standards and procedures proposed by C&H in its permit application are no more stringent than those for any other swine CAFO in Arkansas. This means C&H engineers designed this CAFO the same as any similarly sized CAFO anywhere else in Arkansas, instead of one located in one of the most sensitive areas of the State and directly upstream from our most pristine river.

At a "minimum," Regulation 5 permits require facilities to be assessed, designed, constructed and operated in compliance with the AWMFH. Section 5.402 of Reg. 5 states:

> (A) Designs and waste management plans shall be in accordance with this Chapter and the following USDA Natural Resource Conservation Service technical publications:
>
> - Field Office Technical Guide, as amended
> - Agricultural Waste Management Field Handbook, as amended. (Emphasis added).

The AWMFH provides the requisite guidance to operators and planners to characterize, assess, understand, plan, site, design, and operate an AWMS and is especially relevant to liquid animal waste disposal systems. Recommendations are intended to establish systems that will generally function adequately in a variety of settings. The recommendations are not designed or intended to outline ideal or best management practices. Even if fully complied with, the guidance provided in the AWMFH is not adequate for designing systems that will function adequately in very high risk and very high vulnerability locations. The AWMFH recommends avoiding very high risk and very high vulnerability locations and, since the handbook authors must presume that farmers do not wish to pollute groundwater or cause other environmental problems, they do not identify all actions that should be taken for the design of an AWMS in karst landscapes.

Table 10-4 at page 10-25 of the AWMFH is a table that lists criteria for siting, investigation, and design of liquid manure storage facilities. It uses a matrix with risk on the horizontal scale and vulnerability on the vertical. Vulnerability is "Very High" because of the presence of large voids (karst). The table demonstrates that where there is Very High vulnerability that storage alternatives other than lagoons and waste ponds must be evaluated. Risk is also Very High because of a karst groundwater system that multiple regional studies have shown transports water underground for distances of thousands of feet at rates of hundreds to thousands of feet per day. This transport ultimately discharges water to Buffalo National River (a National Park Service unit) where waters are designated as ERW/NSW. These waters are routinely used by many people for whole body contact. The table demonstrates that where there is Very High Risk other storage alternatives must be evaluated. It is totally inconsistent with the AWMFH that the liquid waste storage at the site is in waste storage ponds lined with native soils with documented liner damage.

The AWMFH requires planning, design, and operation of an AWMS that fully recognizes and accounts for the environmental sensitivity of the area to be impacted. (AWMFH 651.0202 C (17)). C&H co-owner/operator Mr. Jason Henson explained in his deposition that he did not investigate anything prior to purchasing the property and it was therefore critical for the design engineers to explain to the operator the area's special site considerations (p. 127 – 128 at https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Deposition%20Henson,%20Jason%20with%20Exhibits.pdf). While this topic is of great importance, the application prepared by Bass et al. (2016) including information from DeHaan et al. (2012) and used in the subsequent Reg. 5 application failed to: 1) evaluate this topic, and 2) make the sensitivity of receiving waters part of the decision process. In reality, the hydrogeologic conditions at the waste storage ponds and the land application sites are such that there is no reasonable chance that the facility is not already discharging wastes to groundwater and via groundwater to the Buffalo River. The permit application is thus not in compliance with the AWMFH as required under Reg. 5. C&H was not and is not planned, designed, or operated in compliance with Reg. 5.402.

Specific requirements of the AWMFH and the major shortcoming of the current AWMS, permit application, are listed above and will not be repeated here. The AWMFH requires the planner to complete a site evaluation as part of the waste management plan and consult with the decision-maker (the AWMS operator) regarding the findings. Section 651.0200 states:

> "Planning an [AWMS] involves the same process used for any type of natural resource management system, such as an erosion control system. Each system includes a group or series of practices planned, designed, and installed to meet a need. However, different resource concerns, management requirements, practices, environmental effects, and economic effects must be considered.
>
> Planning an AWMS requires the collaboration and combined efforts of a team of people. The decision-maker for the property involved, NRCS specialists and conservationists, county agricultural extension agents, and other professionals often make up the team. Specialists include engineers, geologists, soil scientists, and agronomists."

The firm that prepared the original Notice of Intent (NOI) did not assemble the team of professionals required. It did not involve a geologist or hydrogeologist, a water quality specialist, or NRCS specialists. In fact, the original NOI developers were located in North Dakota, and did not even mention the site's karst geology or its proximity to the Buffalo River. Failure to consider these important factors leads one to conclude that the original NOI planners never understood the complexity of the site. C&H failed to submit a complete site evaluation with its original NOI, and has failed to submit one with its current permit application.

The permit application record does not satisfy the requirements of the AWMFH for C&H's location. The fact that the location drives the selection of the most protective design elements of the AWMFH is ignored. Because C&H is having a measurable impact on aquifers, surface water, and the Buffalo National River, the decision to deny the permit due to the ongoing water quality degradation resulting from this facility is correct.

2. C&H is discharging to waters of the State in violation of 5.102.

The SOB states "The ultimate aim of APC&EC Reg. 5 and the AWMFH is that pollutants are not being released from the facility to waters of the state." The "Harbor Drilling Report" indicates that the waste holding ponds sit atop karst features. Karst features provide a mechanism for rapid transport of wastes that leak from the waste ponds to ground and surface waters. The waste holding ponds were designed and constructed to permit significant waste leakage to "Waters of the State." In the construction certification documents laboratory testing results were given for the compressed soil used for the pond liners. These tests indicated that the initial leakage rates would be 3,448 gal/acre/day for Pond 1 and 4,218 gal/acre/day for Pond 2. The difference is a result of the differing depths of the two ponds. Then estimates were given of the leakage after "manure sealing" –540 gal/acre/day for Pond 1 and 1,008 gal/acre/day for Pond 2. Since Pond 1 has a size of 0.463 acres and Pond 2 has a size of 0.756 acres, leakage per year would be 552,600 gallons. Even though this would be a very significant discharge, multiple lines of evidence suggest that actual leakage from the waste ponds could be much greater than the estimate made by C&H's own engineers. These include the following facts in the record:

1) Only a single analysis was performed to determine whether the soil liners are sufficiently impermeable;

2) There are a large number of chert cobbles present in the native soil liners as discussed in the deposition of Jason Bolenbaugh found at https://www.adeq.state.ar.us/water/bbri/c-and-h/pdfs/2018-09-17/Deposition%20Bolenbaugh.pdf;

3) Erosion rills and desiccation cracks began developing shortly after the ponds were completed, thus compromising the liners;

4) Efforts to repair erosion rills and desiccation cracks, by C&H's own admission (See Ex. 7 to Jason Henson's deposition), resulted in "heavy machinery . . . used to eliminate the erosion rills" (without engineering oversight or review by ADEQ) further compromised the compacted soil liners and liner thickness; and

5) C&H's repeated use of a homemade "agitator" (See J. Henson deposition) to repeatedly stir up solids in pond 1 during waste removal has likely impacted the utility of the native soil liner and any sealing that might occur due to manure solids. (See Sharpley deposition pp. 121-123). Neither pond liner was built to withstand agitation or other methods to remove accumulated solids.

Moreover, sampling from the nearby "house well," trenches, and ephemeral stream confirms significant volumes of waste is seeping into groundwater. Nitrate levels downstream from C&H are more than double upstream values, are highest during low flow periods indicating a groundwater source, and are increasing with time (Petersen 2018). Nitrate slugs have been shown to move past the USGS gaging station at Carver and into the Buffalo River and "time of travel" estimates indicate the source is in the vicinity of C&H (OS 2017 p. 7 – 13). Big Creek has been designated as impaired due to low dissolved oxygen readings resulting from excessive nutrients.

Swine waste leaching into the karst aquifer or washed from surface application fields, and subsequently transported to receiving streams is a probable cause of these declining water quality observations (OS 2017, Petersen 2018, Aley 2018). ADEQ appears to agree based on the statement that "Four assessment units on close proximity to the ongoing operations of the applicant, C&H Hog Farms, Inc., failed to meet the standards in APC&EC Regulation 2 (two sections of Big Creek (Newton County) and two sections of the Buffalo National River)). The assessment units impaired for pathogens and dissolved oxygen and other related water quality data indicate that this facility may be contributing to the water quality impairments observed in Big Creek and the Buffalo National River." SOB p. 8.

In summary, multiple lines of evidence indicate that the prohibition in Regulation 5 against discharging wastes to "Waters of the State" is currently being violated by C&H. That the facility is discharging wastes to Waters of the State is plain both from the current permit, the Regulation 5 permit application and the results of the work done by BCRET, USGS, and the NPS. Furthermore, it cannot be disputed that waste discharges to Waters of the State will continue to occur unless the permit is denied. As mentioned previously, installation of synthetic liners is not a solution to this problem in a karst setting.

3. C&H is contributing to declining water quality in the Buffalo River in violation of Regulation No. 2, the Clean Water Act (see APC&EC Reg. 2, Chapter 2: the Clean Water Act § 303 (33 U.S.C. § 1313) and 40 CFR § 131.12), and AWMFH 651.0202 C (17).

The OS has provided evidence in the form of expert opinions that C&H is having the following impacts on the Buffalo National River:

- Large quantities of nutrients, bacteria, and suspended solids are transported from C&H waste disposal fields to the Buffalo National River with storm event driven surface runoff.
- Groundwater in the Big Creek aquifer near C&H is high in nitrates and likely discharges to a large spring in the Buffalo River's channel.
- Eutrophication and/or assimilation processes driven by agriculturally derived nutrient stimulation has resulted in water quality standards violations and an impairment designation for lower Big Creek within the boundaries of Buffalo National River. This impaired water discharges into the Buffalo River within minutes of passing the USGS Carver sampling station.
- Nutrient loading of the Buffalo River is contributing to nuisance algae blooms, a violation of Regulation No. 2 and aesthetically degrading the visitor experience.
- Pathogen levels in the Buffalo River and Big Creek are now determined to present an elevated risk of water-borne illness to visitors recreating in close proximity to C&H.

OS has shown by a preponderance of the evidence that swine waste is leaching into the karst geology of Big Creek combined with episodic discharge from application fields during storm events, which is all subsequently transported to Buffalo National River (OS 2017, Petersen 2018, Aley 2018, ADEQ Draft 2018 Impaired Water Bodies 303(d) List). The SOB states that "Four assessment units in close proximity to the ongoing operations of the applicant, C&H Hog Farms, Inc., failed to meet the standards in APC&EC Regulation 2 (two sections of Big Creek (Newton County) and two sections of the Buffalo National River). The assessment units impaired for pathogens and dissolved oxygen and other related water quality data indicate that this facility may be contributing to the water quality impairments observed in Big Creek and the Buffalo National River." SOB p. 8. We agree.

The Buffalo National River is designated an ONRW. The CWA established an "Antidegradation Policy." The antidegradation policy is currently being violated because the existing C&H facility contributes significant nutrient and pathogen loads to the Buffalo River, and the river's pre-existing water quality has been degraded – a violation of the CWA and the AWMFH provision to assure that the designated water use (in this case ONRW, ERW and NSW) is protected. (AWMFH 651.0202 C (17).

The CWA also requires establishment of "Designated Uses" for waterbodies. Designated uses include such categories as Public Water Supply, Fishable/Swimmable, and Outstanding National

Resource Waters. Water quality standards are established based on designated use. Under the Antidegradation Policy, waterbodies will not be degraded with pollutants such that they no longer meet their most restrictive designated use. CFR 40 § 131.12 states:

> (a) The State shall develop and adopt a statewide antidegradation policy. The antidegradation policy shall, at a minimum, be consistent with the following:
>
> > (1) Existing instream water uses and the level of water quality necessary to protect the existing uses shall be maintained and protected.
> >
> > (2) Where the quality of the waters exceeds levels necessary to support the protection and propagation of fish, shellfish, and wildlife and recreation in and on the water, that quality shall be maintained and protected unless the State finds, after full satisfaction of the intergovernmental coordination and public participation provisions of the State's continuing planning process, that allowing lower water quality is necessary to accommodate important economic or social development in the area in which the waters are located. In allowing such degradation or lower water quality, the State shall assure water quality adequate to protect existing uses fully. Further, the State shall assure that there shall be achieved the highest statutory and regulatory requirements for all new and existing point sources and all cost-effective and reasonable best management practices for nonpoint source control (emphasis added).
> >
> > > (i) The State may identify waters for the protections described in paragraph (a)(2) of this section on a parameter-by-parameter basis or on a water body-by-water body basis. Where the State identifies waters for antidegradation protection on a water body-by-water body basis, the State shall provide an opportunity for public involvement in any decisions about whether the protections described in paragraph (a)(2) of this section will be afforded to a water body, and the factors considered when making those decisions. Further, the State shall not exclude a water body from the protections described in paragraph (a)(2) of this section solely because water quality does not exceed levels necessary to support all of the uses specified in section 101(a)(2) of the Act.
> > >
> > > (ii) Before allowing any lowering of high water quality, pursuant to paragraph (a)(2) of this section, the State shall find, after an analysis of alternatives, that such a lowering is necessary to accommodate important economic or social development in the area in which the waters are located. The analysis of alternatives shall evaluate a range of practicable alternatives that would prevent or lessen the degradation associated with the proposed activity. When the analysis of alternatives identifies one or more practicable alternatives, the State shall only find that a lowering is necessary if one such alternative is selected for implementation.
> >
> > (3) Where high quality waters constitute an outstanding National resource, such as waters of National and State parks and wildlife refuges and waters of

exceptional recreational or ecological significance, that water quality shall be maintained and protected. (emphasis added).

C&H's AWMS component planning, design, and management was not undertaken in a manner that assures the designated water uses of Big Creek and the Buffalo River are protected. Planning requirements as stated in the AWMFH were not followed. These planning requirements not only mandate the additional geotechnical data as outlined in the SOB, but also the ultimate design and operation of a facility that has "minimum" water quality impacts. The AWMFH states:

> The sensitivity of lakes, streams, or groundwater aquifers to contaminants in the agricultural waste should be evaluated and made part of the decision process of whether to allow discharge. Receiving water sensitivity must also be considered when establishing the intensity of management and level of efficiency needed to avoid or minimize accidental spills and **to assure that the designated water use is protected.** (AWMFH 651.0202 C (17). (emphasis added).

The Buffalo River deserves the highest protection of any receiving stream in the State. We outlined this position in our previous comments noting its ONRW status (OS 2017 comments p.7) of the Buffalo River and the accompanying antidegradation policy. We also discussed the importance of Buffalo National River as an economic and tourism resource for the State in our 2017 cover letter and comments (OS 2017 p. 36 – 55).

Permit denial is appropriate. Issuing a permit to C&H would violate Regulation 5 and the CWA. C&H is contributing to water quality declines and stream impairment. This has resulted in the Buffalo River and Big Creek no longer meeting their designated uses as ERW/NSW and fishable/swimmable.

4. The number of swine at the facility has increased in violation of the 2016 APC&EC moratorium Reg. 5.901(D).

The NOI submitted by C&H on June 25, 2012 for coverage under the general NPDES permit, ARG590001, described C&H as a "2,500 head farrowing farm." It also stated that the barns would have a "maximum capacity of 6,503 head of swine weighing an average 150 lbs." (Section C: "*Design Report*," p. C-1) The breakdown was:

> 3 Boars @ 450 lbs.
> 2,100 Gestation Sows @ 375 lbs
> 400 Lactating Sows @ 425 lbs
> 4,000 Nursery Pigs @ 10 lbs

Section C2: "*Design Calculations*," p. C-3.

It appears the 4,000 "Nursery Pigs" was estimated by assuming that a nursing litter would be 10 piglets per sow being weaned. The weaning process requires 23 to 24 days (www.nationalhogfarmer.com/health-diseases/0615-producing-quality-pigs.) The 4,000 estimate is an average but this number will be relatively constant because as sows give birth to new litters, litters are weaned and then shipped off-site.

Reg. 5.901(D) states that "A permit renewal, permit modification, or new permit issued pursuant to Reg. 5.901(C) shall not increase the number of swine permitted at a facility." However, the "Application Packet" submitted by C & H on April 6, 2016 in support of its request for a Reg. 5 permit (these numbers are repeated in the SOB) and it states C&H Hog Farms now seeks a permit for:

6 Boars @ 450 lbs
2,252 Gestating Sows @ 425 lbs
420 Lactating Sows@ 400 lbs
750 Nursing Pigs @ 14 lbs.

C & H Hog Farms, Inc., "*Application for Regulation 5 Permit, Engineering Plans and Review,*" p. 6.

In contrast to its 2012 NOI, in its Reg. 5 permit application C & H defines "Nursery Pigs" as pigs that have completed the weaning process. The "750" is arrived at as the average of 1,500 weaned pigs on the farm before the weekly shipment and the zero number on the farm just after the shipment. *Id.* at pp. 5-6. This ignores pigs in the weaning process that weigh from 3 to 5 pounds at birth and 14 pounds or more when weaned. (www.nationalhogfarmer.com/health-diseases/0615-producing-quality-pigs.) The weaning period is from 23 to 24 days. (*Id.*) In order to ship 1,500 pigs at a given time, there must be over 4,000 pigs being weaned at the time of the shipment.

If C & H's Reg. 5 permit application had used the same method for determining the number of "Nursery pigs" as in the original NOI, the numbers would currently be:

6 Boars @ 450 lbs
2,252 Gestating Sows @ 425 lbs
420 Lactating Sows @ 400 lbs
4,200 Nursing Pigs @ 10 lbs

Thus, the original approved NOI is being violated since there are now approximately 6,878 pigs on the farm instead of the original 6,503. If approved, the new Regulation 5 permit would violate Reg. 5.901(D).

Comparisons of pounds of swine and waste permitted in the original NOI and the current permit application further confirms these estimates. In the NOI (DeHaan, Grabs & Associates, 2012), C&H was permitted to raise 998,850 pounds of swine producing 1.5 million gallons of waste. The permit application lists 1,138,000 pounds of swine (Hancock et al., 2016) producing 1.9 million gallons of waste (February 2017 SOB p. 3).

In addition, the waste calculations in the permit application are incorrect. Along with the boars and sows, waste volumes should have been based on 4,200 pigs weighing 10 pounds instead of 750 pigs weighing 14 pounds. This means the volume of waste will be significantly greater. The permit application violates Reg. 5.901(D).

Expert Report

C&H Hog Farms Hearing

Analysis of Water Quality, Groundwater Hydrology, Surface Water Hydrology, and Aquatic Biology

May 31, 2018

Revised October 16, 2018

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Attachment 2

Table of Contents

List of figures

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1.0 Introduction

I have prepared this report to present information, data, and opinions concerning the water quality and aquatic biology in and around the Big Creek watershed near Mt. Judea, Arkansas, and the potential effects of operation of C&H Hog Farms on water quality, groundwater hydrology, surface water hydrology, and aquatic biology in the region. Because of issues with the storm data and to address a lack of previous consideration of the karst geology and its effect on groundwater hydrology, I have chosen to focus on samples from groundwater and on samples from streams collected at times when the streamflow was likely to have been dominated by contributions from groundwater. Much of the data collected near C&H Hog Farms has been collected by the University of Arkansas Big Creek Research and Extension Team (BCRET) (https://bigcreekresearch.org/). BCRET sampling sites are shown on figure 1. This report has been prepared at the request of Mr. Sam Ledbetter with McMath Woods.

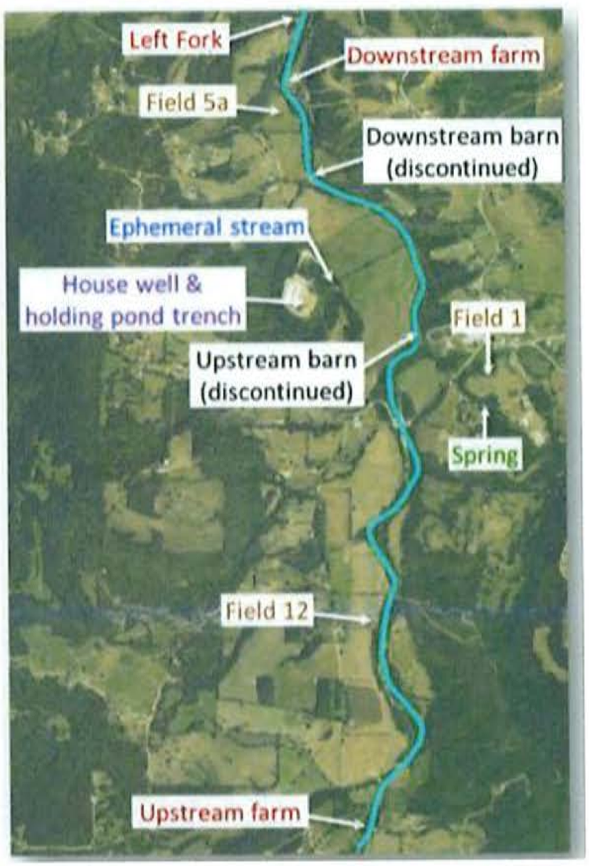


Figure 1. Location of BCRET water-quality sampling sites (from the BCRET January-March 2018 Quarterly Report)

2.0 Qualifications and Experience

I am an aquatic biologist and a water-quality hydrologist and worked for more than 36 years with the U.S. Geological Survey Arkansas Water Science Center (later part of the Lower Mississippi-Gulf Water Science Center). During much of that time I was responsible, either individually or as part of a study team, for conducting several studies of surface-water and groundwater quality and aquatic biology in the Ozarks of Arkansas, Missouri, and Oklahoma. See appendix A for a more detailed curriculum vitae.

3.0 Summary of Opinions

The following is a summary of my opinions. These opinions are described in greater detail in later sections of this report:

(1) The karst topography and geology of the area near C&H Hog Farms, including part of Big Creek located upstream from BCRET monitoring site BC6 and downstream to the Buffalo River, present issues for agricultural activities and the collection of data used for hydrologic studies. These issues are not applicable, or not applicable to the same degree, in areas without karst. Karst-specific attributes include rapid movement of groundwater (up to thousands of feet to miles per day; Brahana and others, 2017), little decrease of contaminants, relatively common movement of groundwater beneath surface elevation divides, loss of surface water from streams to groundwater, and gain of groundwater to streams. Studies or data required to determine specific groundwater flow pathways and loads for contaminants of concern were not available prior to the operation of C&H Hog Farms. Lack of pre-development baseline water-quality data and a basic understanding of the karst hydrology of the Big Creek watershed impede efforts to analyze and interpret water quality results. New hydrologic information gathered since that time has answered some questions, yet many significant questions remain that can only be resolved through alteration of the BCRET study design and collection of systematic dye tracing studies. These include questions about groundwater movement, gaining and losing reaches of Big Creek, and measurement of storm flow concentrations and loads in a manner that transport of nutrients and other constituents out of the Big Creek watershed and into the Buffalo River can be quantified.

(2) As is most often the case in similar situations, environmental sampling and testing adequate to define pre-existing conditions prior to the operation of this facility did not occur. Several scientific investigations could have been conducted after operation began or could be conducted in the future that would provide information about the hydrology and geology of the vicinity. The recommendations of the expert review panel (https://bigcreekresearch.org/project_reports/docs/Review%20Panel%20Report%20-%20May%2019%202014.pdf) provide some examples of appropriate investigations that are lacking. These include a seepage survey along Big Creek, streamflow and a rating curve for BC6, source tracking using isotopic methods or analysis of emerging contaminants such as antibiotics, and better sampling of storm events.

(3) The absence of representative data associated with storm flows precluded the analysis of storm data and accurate estimation of seasonal or annual loads (for example the pounds of nitrogen moving past a site in a year). Because much of the mass of sediment and nutrients is transported during storm events, **this is a critical shortcoming of the available dataset**. This was pointed out by the expert review panel but their concerns remain unresolved. As a result, an estimated 80 to 90 percent of the nutrient transport and fate processes remain unassessed.

(4) My analysis of water-quality data collected by BCRET focused on base flow conditions when streamflow is dominated by groundwater input. Results from sites BC6 (upstream from C&H Hog Farms facilities and associated waste ponds and slurry spreading fields) and BC7 (downstream) indicate that the operation of the currently permitted Animal Waste Management System is having a negative effect on the water quality of Big Creek during base flow.

(5) The frequency and seasonal persistence of dissolved oxygen concentrations of Big Creek at Carver that are often substantially below the state standard may be causing detrimental effects on aquatic species and fish and macroinvertebrate (aquatic insects, etc.) communities of Big Creek and the Buffalo River. The proximity to the Buffalo River and the applicable anti-degradation policy are another immediate concern.

(6) Increasing trends in some nutrients, dissolved organic carbon, and *E. coli* in samples from site BC4 (Ephemeral Stream) indicate that inputs of these constituents to Big Creek are increasing and potentially affecting water quality of Big Creek near the hog farms and downstream from the confluence of this stream with Big Creek. If concentrations are increasing in base flow samples it is likely that concentrations in storm water also are increasing—and concentrations are almost certainly higher in the storm water than in base flow.

(7) Comparison of concentrations of total nitrogen and total phosphorus at BC7 to biological thresholds for nutrients in wadeable Ozark streams indicates that existing concentrations are approaching (total nitrogen) or have exceeded (total phosphorus) concentrations affecting periphyton (attached algae), macroinvertebrate (aquatic insects, etc.), and fish communities.

(8) Increasing trends in concentrations of three nitrogen constituents in samples from the BCRET House Well site indicate contamination of the shallow groundwater aquifer. The steadily increasing pattern observed for several parameters indicates a constant input to the local aquifer feeding the well. Results at BC7 also indicate a strong correlation between increasing nitrate concentrations and time (i.e., date) during low flow periods characterized by increased groundwater discharge.

(9) Water-quality from a trench downslope from the two waste holding ponds indicates that the contents from both ponds are seeping into the downslope trench.

Much of the above information can be summarized in the following tabulation of pertinent results indicating existing conditions and water-quality trends.

Table 1. Summary of most pertinent results indicating existing conditions and water-quality trends

Constituent or attribute	Impact	p-value
Ammonia	Increasing at House Well	<0.001
Nitrate	Increasing at BC7	0.07
Nitrate	Increasing at Ephemeral Stream	0.002
Nitrate	Increasing at House Well	<0.001
Total nitrogen	BC7 minus BC6 increasing	0.095
Total nitrogen	Increasing at Ephemeral Stream	<0.001
Total nitrogen	Increasing at House Well	<0.001
Dissolved phosphorus	BC7 minus BC6 increasing	0.091
Dissolved phosphorus	Increasing at Ephemeral Stream	0.011
Dissolved organic carbon	Increasing at Ephemeral Stream	0.01
E. coli	Increasing at Ephemeral Stream	0.08
Chloride	Decreasing at BC6 but no trend at BC7	0.03
Chloride	BC7 minus BC6 increasing	0.04
Nutrient Management Watershed pasture yields	Nitrate, total nitrogen, and chloride significantly higher	
(compared to BC6 watershed)	Total nitrogen decreasing, no trends for nitrate and chloride	
Trench data	Several constituents indicate leakage from ponds	
Biology data	Total phosphorus exceeding threshold of community impact	
DO data	DO standard already exceeded 50-60 days per year at Carver	

4.0 Bases for Opinions

In preparing this report I used Big Creek Research and Extension Team (BCRET) data and information supplied by Dr. Andrew Sharpley or contained in BCRET quarterly reports, and:

(1) Other information from the BCRET website (https://bigcreekresearch.org/)
(2) U.S. Geological Survey streamflow and water-quality data (available from their website)
(3) Permitted Concentrated Animal Feeding Operation Assessment, Buffalo National River by David N. Mott (2016)
(4) A March 19, 2018 visit to parts of the Big Creek watershed including BCRET sites BC6, BC7, and Ephemeral Stream and the U.S. Geological Survey sites at Carver and Mt. Judea
(5) A National Park Service/Arkansas Department of Environmental Quality water quality dataset for several sites on the mainstem of the Buffalo River and its tributaries.

(6) Several reports and journal articles cited and listed below
(7) My professional experience and expertise, see appendix A for additional information.

5.0 Location, Environmental Setting, and Karst Topography and Geology

C&H Hog Farms is located in Newton County, Arkansas about 0.7 mile northwest of the community of Mt. Judea and 0.4 mile west of Big Creek. Mt. Judea has a population of less than 460 (457 people live in the 72655 zip code area which includes Mt. Judea; 2010 census) (https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml?src=bkmk).

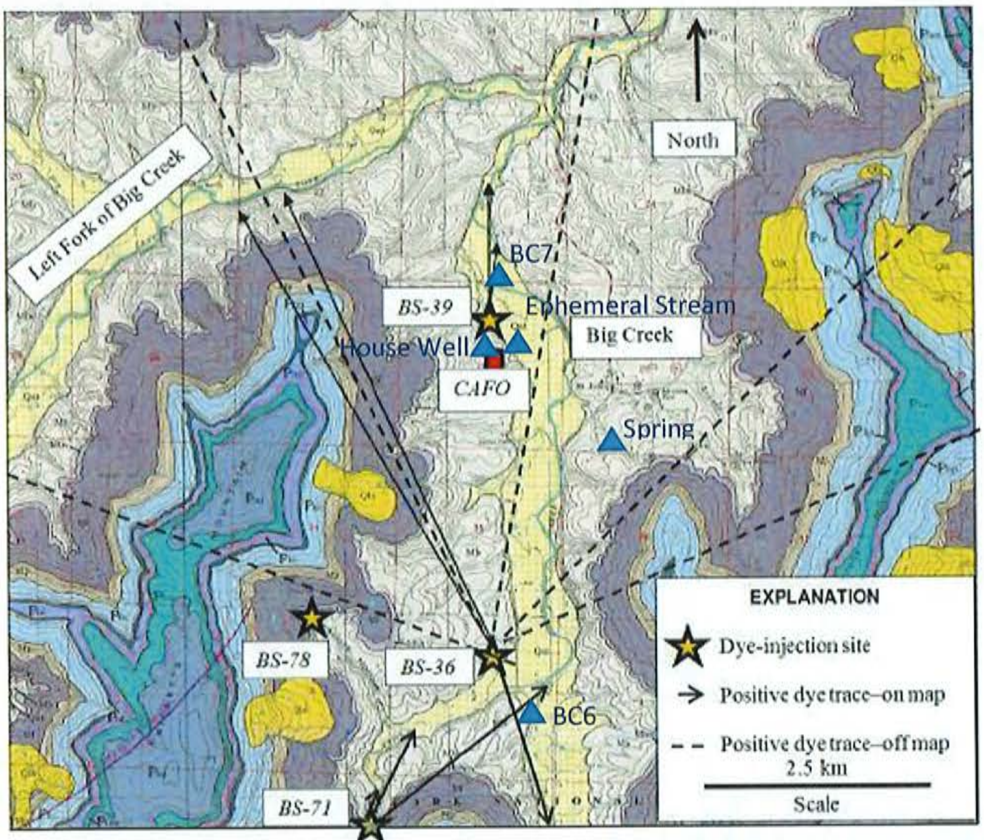
Big Creek flows northward, east of the hog farm and west of Mt. Judea. It has a watershed area of approximately 89.8 square miles at its confluence with the Buffalo River, which is part of the Buffalo National River (Watershed Conservation Resource Center, 2017). The land use within the watershed is approximately 82.2 percent forest, 15.3 percent agriculture/grass, and 2.5 percent other (Watershed Conservation Resource Center, 2017).

The Buffalo River is listed as an Extraordinary Resource Water and Natural and Scenic Waterway in the Arkansas Pollution Control and Ecology Commission's Regulation 2 (Arkansas Pollution Control and Ecology Commission, 2017).

Big Creek and nearby reaches of the Buffalo River are considered to be within the Boston Mountains ecoregion by the Arkansas Pollution Control and Ecology Commission (Regulation 2; Arkansas Pollution Control and Ecology Commission, 2017). Near Mt. Judea, Big Creek flows through alluvial deposits overlying the Boone Formation, a karstic limestone formation with interbedded chert. The Boone Formation extends upstream along Big Creek to about 3 miles south of Mt. Judea (which is about 1 mile upstream of BC6, the site upstream from C&H Hog Farms monitored by BCRET).

In my opinion, the karst topography and geology of the area near C&H Hog Farms, including part of Big Creek located upstream from BCRET monitoring site BC6 and downstream to the Buffalo River, present issues for agricultural activities and the collection of data used for hydrologic studies. These issues are not applicable, or not applicable to the same degree, in areas without karst. These karst-specific attributes include rapid movement of groundwater (up to thousands of feet to miles per day; Brahana and others, 2017), little decrease of contaminants, relatively common movement of groundwater beneath surface elevation divides, loss of surface water from streams to groundwater, and gain of groundwater to streams. Studies or data required to determine specific groundwater flow pathways and loads for contaminants of concern were not available prior to the operation of C&H Hog Farms. Lack of pre-development baseline water-quality data and a basic understanding of the karst hydrology of the Big Creek watershed impede efforts to analyze and interpret water quality results. New hydrologic information gathered since that time has answered some questions, yet many significant questions remain that can only be resolved through alteration of the BCRET study design and collection of systematic dye tracing studies. These include questions about groundwater movement, gaining and losing reaches of Big Creek, and measurement of storm flow concentrations and loads in a manner that transport of nutrients and other constituents out of the Big Creek watershed and into the Buffalo River can be quantified.

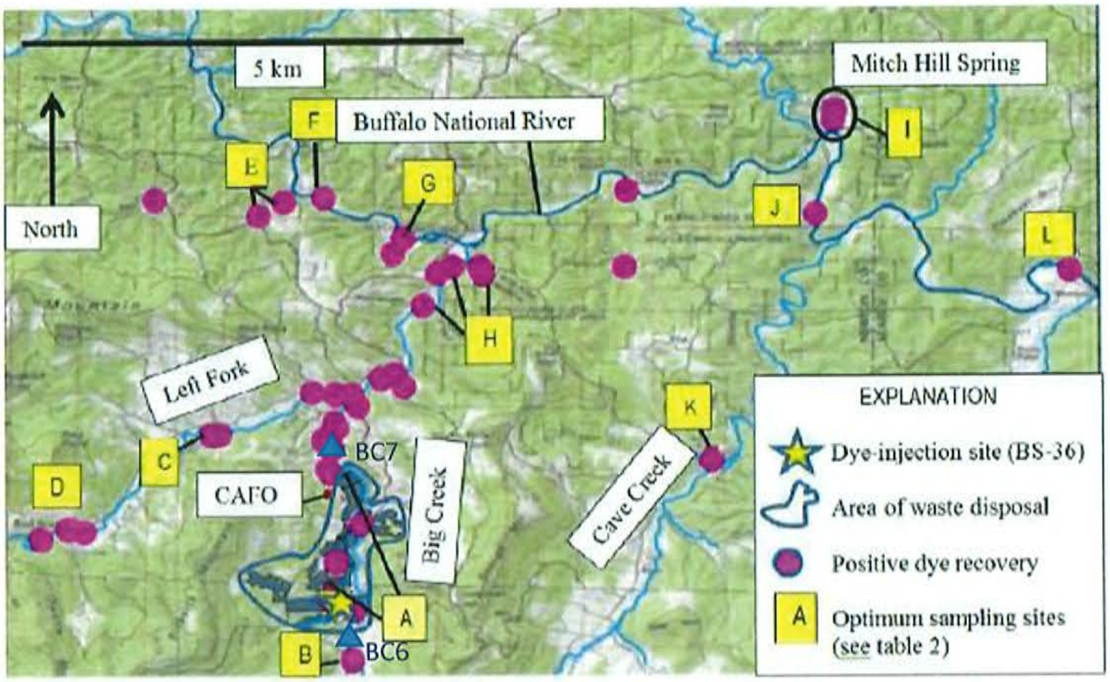
The dye tracing results shown in figures 2 and 3 (Brahana and others, 2017) suggest that BC6 may not be an appropriate "control" site because of the possibility of south flowing groundwater moving from one of the fields receiving hog waste to Big Creek upstream from BC6. The dye traces (figs. 2 and 3) also show the potential for wide ranging movement of contaminants from the area of the application fields to locations in the Big Creek watershed, Cave Creek watershed, and in Buffalo National River (including Mitch Hill Spring on the opposite side of the Buffalo River).



Base map from Braden and Ausbrooks, 2003

Geologic map showing point-to-point dye-tracing results in the area of the CAFO and its spreading fields. Solid arrows that emanate from the injection points show the locations of groundwater recovery sites on the map. Dashed lines from injection well BS-36 extend beyond the area shown on this map, with the full observed extent shown on figure 9. Actual flow paths in the subsurface are substantially more complex than the straight lines show. Tracing results shown here are groundwater-level dependent.

Figure 2. Dye tracing injection and recovery sites and selected BCRET sampling sites (modified from Brahana and others, 2017)



. Flow from BS-36 during high flow after eosine injection on May 12, 2014. Dye was positively traced to 36 sites (springs and streams). Letters (yellow squares) show recommendations for sites to sample for evaluating contamination in the future. The dye-trace results show the full dispersive extent of karst flow in the subsurface into other surface-water basins, the Buffalo National River, and even beneath the Buffalo River to Mitch Hill Spring, identified by the black circle. Dark green rectangular patterns within area outlined around dye-injection site (yellow star) represent waste spreading fields. Five positive dye traces were recovered from the Buffalo National River during this test.

Figure 3. Dye recovery sites associated with a single injection site near BCRET site BC6 (blue triangle) (modified from Brahana and others, 2017)

Much of the middle section of Big Creek is underlain by the Boone Formation, while its headwaters and the tributaries originate in geologic formations composed primarily of sandstone and shale (Braden and Ausbrooks, 2003; Brahana and others, 2017). The Boone Formation is a relatively thick (approximately 120 to 400 feet) limestone with locally variable amounts of interbedded chert (chert is a relatively impervious rock composed of silicon dioxide). Chert layers can impede the movement of water through the Boone Formation.

Chert layers are common in the streambed of Big Creek just upstream from BC7 and are likely forcing groundwater of unconfirmed origin back into the stream channel. The section of stream between BC6 and BC7 contains reaches that lose surface water to the groundwater and that gain streamflow from the groundwater (these are referred to as "losing" and "gaining" reaches). Big Creek between the two sites can go dry while both the upstream and the downstream sites are still flowing. The upstream site can also go dry while the downstream site is still flowing. Therefore, the reach of Big Creek from above the upstream site to just above the downstream site is a losing reach. The downstream site has not gone dry since monitoring began, and the section is gaining water from groundwater inflow. It is not uncommon for BC6 to be dry or not flowing when the streamflow at BC7 is less than about 3 cubic feet per second. Most, if not all, of the BC7 flow at these times is groundwater that has flowed from the Boone Formation into Big Creek. The recharge area for the spring(s) feeding Big Creek upstream from BC7 has not been delineated.

Continuous streamflow data from USGS gages at BC7 and about 4 river miles downstream near Carver (Big Creek at Carver) suggest that the section of Big Creek between these two gages is losing water to the Ordovician aged limestones underlying the Boone Formation, although some water may be flowing through gravel bars near the gage rather than flowing into underlying limestones. During periods of low flow at Carver (less than 6 cubic feet per second) it is not uncommon for streamflow at Carver to be less than streamflow at BC7. This water lost to the karst formations may resurface in the Buffalo River downstream of the confluence with Big Creek. In a July 2003 study of gaining and losing reaches of the Buffalo River, a reach just downstream from Big Creek gained a substantial volume of water. It gained approximately 8.5 cubic feet per second more than could be attributed to inflow from Big Creek (Moix and Galloway, 2005).

A seepage study of Big Creek to determine gaining and losing reaches of the stream followed by additional dye trace studies would provide insight into the pathways of nutrients from Big Creek to the Buffalo River. In the July 2003 study about one-third (the surface water inflow from Big Creek plus the approximate 8.5 cubic feet per second gain) of the flow at the end of the gaining Buffalo River reach was potentially from the Big Creek watershed. This is important because groundwater in the area of C&H Hog Farms (House Well) could have average concentrations more than seven times higher than average nitrate concentrations in the Buffalo River at Hasty (Watershed Conservation Resource Center, 2017).

6.0 Limitations of Existing Water-Quality Data

In my opinion, as is most often the case in similar situations, environmental sampling and testing adequate to define pre-existing conditions prior to the operation of this facility did not occur. Several scientific investigations could have been conducted after operation began or could be conducted in the future that would provide information about the hydrology and geology of the vicinity. The recommendations of the expert review panel (https://bigcreekresearch.org/project_reports/docs/Review%20Panel%20Report%20-%20May%2019%202014.pdf) provide some examples of appropriate investigations that are lacking. These include a seepage survey along Big Creek, streamflow and a rating curve for BC6, source tracking using isotopic methods or analysis of emerging contaminants such as antibiotics, and better sampling of storm events.

If site specific groundwater and geologic data had been collected prior to the operation of the hog farm much more would be known regarding karst groundwater flow and subsurface contaminant pathways. Water quality data should have been collected prior to the operation of the hog farm given the magnitude of concerns. The fact that it was not is beyond the control of BCRET. Nonetheless, new information about the hydrology and geology of the Big Creek area would provide helpful insight. Studies/needs include installation of a streamgage at BC6, a seepage study of Big Creek to determine gaining and losing reaches of the stream, additional dye traces of the area to better determine groundwater pathways, subsurface water quality investigations below the spreading fields to quantify infiltration of contaminants to shallow karst groundwater, and isotope studies to better determine sources of nutrients in Big Creek. These are among the recommendations of an expert panel formed to review the current and planned BCRET monitoring program (https://bigcreekresearch.org/project_reports/docs/Review%20Panel%20Report%20-%20May%2019%202014.pdf). The additional information would add to the validity of interpretations based on the existing water-quality data.

In my opinion, the absence of representative data associated with storm flows precluded the analysis of storm data and accurate estimation of seasonal or annual loads (for example the pounds of nitrogen moving past a site in a year). Because much of the mass of sediment and nutrients is transported during storm events, this is a critical shortcoming of the available dataset. This was pointed out by the expert review panel but their concerns remain unresolved. As a result, an estimated 80 to 90 percent of the nutrient transport and fate processes remain unassessed.

Because reliable monitoring of stormflow has not been performed, my analysis of water-quality data from streams was limited to samples collected during conditions when streamflows were primarily base flow (base flow is input or effluent from groundwater; specifically, samples that I identified as "base" samples after looking at the "base" or "storm" designation in the BCRET database and USGS 15-minute streamflow values for BC7—see below for more details). Hereafter, in most cases I will refer to streamflow associated with these "base" samples as base flow.

A very large percentage of the constituent loads (mass per unit time, a function of the multiplication of concentrations and streamflows) and streamflows typically occurs during a few days of the year. Therefore, to get a complete description of the water quality of a stream it is important to measure streamflow and to collect representative water-quality samples not just during periods of low flow, but also during periods of runoff-induced high streamflow (i.e., during storm events). Concentrations of constituents (particularly those associated with suspended particles) are not uniformly distributed vertically or horizontally in a stream cross-section because of localized inflows and the spatial variability of water velocity in a cross-section. Collecting representative samples during these periods of high streamflow is a difficult and expensive endeavor. At one end of the storm event sampling-method continuum would be collecting grab samples at a single time during a few events. At the other end of the continuum would be collecting several integrated samples from the entire depth of several vertical transects during a number of storm events; supplementing this information with samples collected using automatic samplers is also beneficial. Automatic samplers are helpful because they can sample during an entire storm event, however, they pull their samples from a discrete point in the stream and this may or may not yield samples representative of the entire stream cross section. The procedure (U.S. Geological Survey, 2006) for U.S. Geological Survey sampling of flowing waters (waters with velocities of greater than 1.5 feet per second) is to use one of two sampling methods (Equal Width Increment, EWI; or Equal Discharge Increment, EDI). The most common, because of ease of use, is the EWI method. The method requires use of an isokinetic (collecting water in proportion to the water velocity), depth-integrating sampler lowered from surface to full depth at multiple verticals across a stream cross section. The samples from the individual verticals are then composited and divided by a splitter into required bottles for laboratory analysis to maintain the representativeness of the water placed in each laboratory bottle.

The BCRET sampling relied on grab samples exclusively during base flows and a combination of grab samples and auto-collected samples during storm flows. These samples are not likely to be representative except during times of low water velocities. They are not representative during storm events or during base flow times with higher velocities. The BCRET samples collected with ISCO brand automatic samplers were collected from discrete points in the stream. The representativeness of these storm samples cannot be confirmed and I did not include storm data in my analyses for the following reasons:

- Edwards and Glysson (1999) describe considerations for use of automatic samplers--including advantages and disadvantages, optimum criteria, placement of sampler intake, orientation of sampler intake, and substantial time for post-collection data analysis. I have seen no documentation and I am not aware of these items being considered or implemented.
- Martin and others (1992) found that concentrations of dissolved constituents were not consistently different among grab samples and integrated samples. However, concentrations of suspended sediment and total phosphorus were significantly lower in surface-grab samples than in integrated samples. Harmel and others (2010) in a study of grab and integrated samples from storm waters at sites with drainage areas similar to the Big Creek sites found grab sample concentration errors (relative to integrated sample concentrations) of more than 5 percent in 52 percent of the nitrate samples, 74 percent of the ammonia samples, and 81 percent of the dissolved phosphorus samples. For the constituents associated with suspended materials, errors of more than 5 percent for 68 percent of the total phosphorus samples and 71 percent of the suspended sediment samples were reported. It was not uncommon (in 7 to 32 percent of comparisons) for these for constituents to have greater than a 30 percent error between the two sampling procedures. Unfortunately, much of the difference between concentrations of water-quality variables that include a suspended component (such as total nitrogen, total phosphorus, total suspended solids, bacteria) would occur between samples collected during the elevated streamflow conditions associated with storms.
- In addition to samples needing to be representative of the stream profile, the sampling design must be representative of all flow conditions throughout the study period. Much of the streamflow and much of the transport of nutrients and other constituents occurs during a few days each year. Based on USGS streamflow data at BC7 (Big Creek near Mt. Judea, station 07055790) for calendar years 2014-2017, 25 percent of the total flow occurred during only 1 percent of the days (11 days) (fig. 4). Water-quality samples were collected at BC7 on only 2 of these 11 days. Samples were collected the following day for 4 of the 11 days.

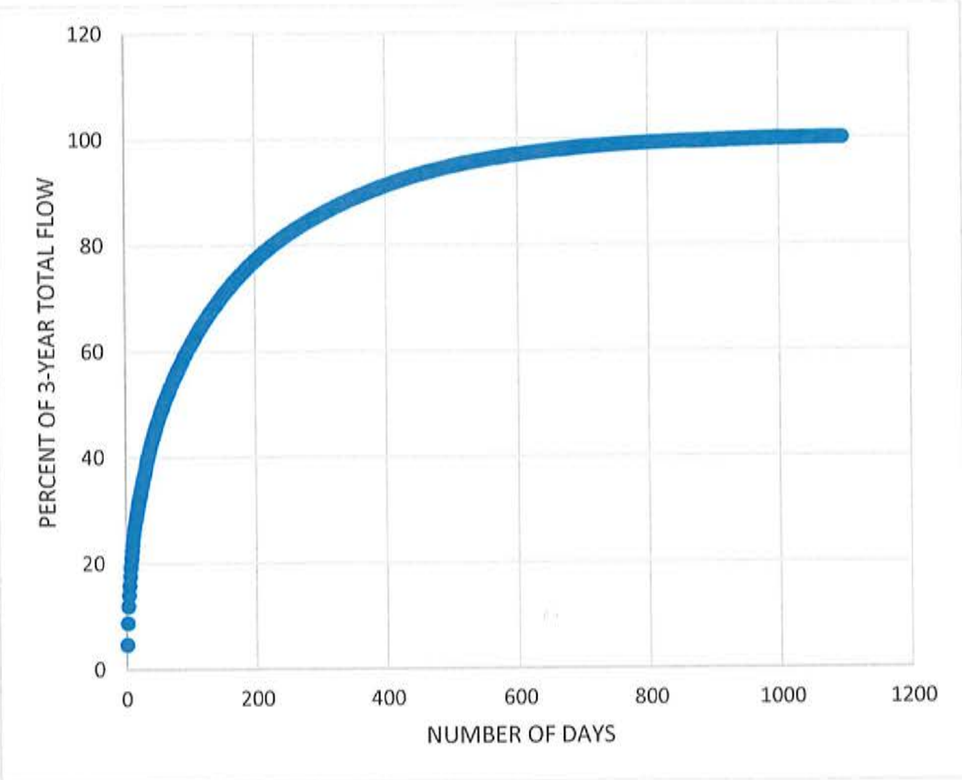


Figure 4. Cumulative streamflow for USGS site 07055790 (colocated with BC7) for calendar years 2014 through 2017

- Storm events were not consistently sampled. In 2017 some substantial stormflows were not sampled (fig. 5; blue dots show 15-minute streamflow value at time of sampling). Calendar year 2017 was typical of the total sampling period.
- In addition to the potential errors in characterization of water quality that can be attributed solely to collecting grab samples (versus integrated samples or ISCO samples), there are potential errors resulting from differences in ISCO sampling frequency at BC6 and BC7. The number of ISCO samples at the two sites was substantially different—5 at BC6 and 15 at BC7, through December 2017 (table 2). The ISCO sampling dates at BC6 ranged from June 27, 2014 to May 8, 2015 while the sampling dates at BC7 ranged from October 14, 2014 to June 6, 2017; **2 years of ISCO sampling occurred at BC7 with no ISCO samples being collected at BC6**. Only on one occasion (and these samples were collected a day apart) were a pair (one from BC6 and one from BC7) of ISCO samples collected during the same storm event.

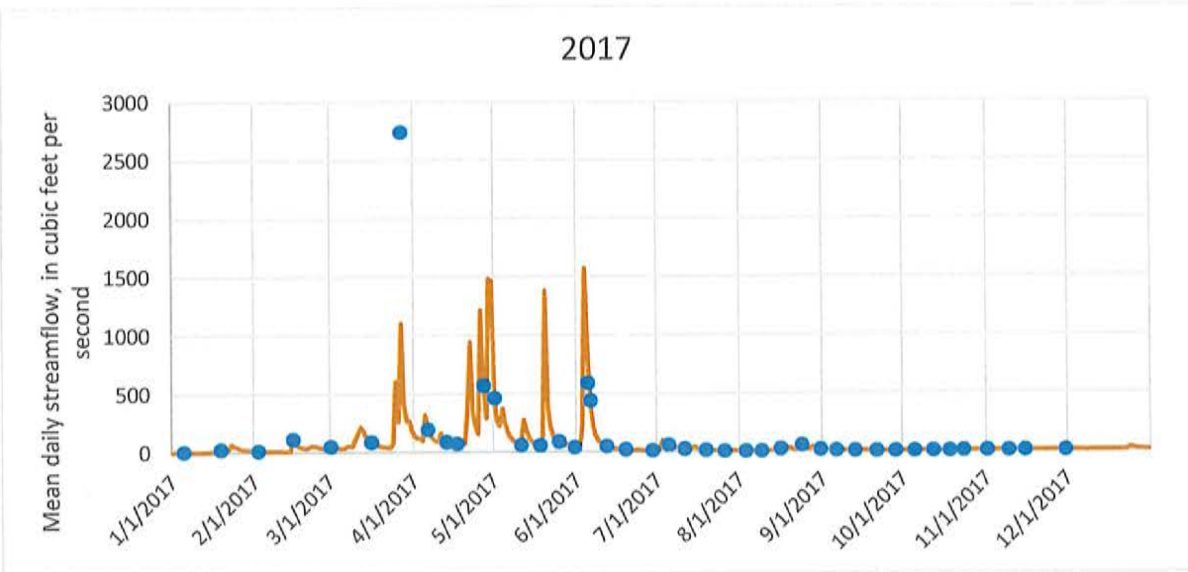


Figure 5. Sampling dates (blue dots) and associated mean daily streamflow at USGS site 07055790 (colocated with BC7)

Table 2. Comparison of ISCO automatic sampler collections and collection dates (through December 2017)

	BC6	BC7
Number of ISCO samples	5	15
First sample date	6/27/2014	10/14/2014
Last sample date	5/8/2015	6/6/2017
Number of dates with ISCO samples at other sites	1*	1*

*one day apart

- I visited the two sites on March 19, 2018. At both sites the intake tubing for the ISCO sampler was lying loose on the stream bottom without any protective housing to keep it stable during elevated streamflows. This would limit the ability of the sampler to collect representative samples.

- Lack of standard quality assurance and quality control checks for automated samplers are also a concern. A comparison of concentrations of dissolved phosphorus, total phosphorus, ammonia, nitrate, total nitrogen, total suspended solids, and dissolved organic carbon for five paired storm samples (four "storm, ISCO" with "storm, grab"; one "storm, ISCO" with "base, grab") indicated that ISCO and grab sample concentrations were not comparable. Relative percent differences for pairs of dissolved phosphorus samples ranged from -21 to 156 percent, total phosphorus from -94 to 172 percent, ammonia from -200 to 129 percent, nitrate from -192 to -17 percent, total nitrogen from -18 to 155 percent, total suspended solids from -31 to 198 percent, and dissolved organic carbon from -31 to 128 percent. While some of these differences are undoubtedly because of differences in the timing of the sample collection, a properly designed quality assurance plan would have identified issues that at this point appear unresolvable. The ISCO samples are composites--presumably spanning the rising limb, peak, and part of the falling limb of the storm hydrograph (i.e. when the water levels in the stream are rising, peaking, and falling) while the "storm,grab" samples that were paired with ISCO samples were collected at the time when the ISCO samples were "collected." The time shown in the BCRET water-quality database for "storm,grab" samples closely corresponds to the time shown for the ISCO samples and therefore the ISCO time apparently does not refer to the time when the water was pumped from the stream because the grab sample is collected when the technician arrives at the site to collect the ISCO sample from the ISCO shelter (inferred from written communication from Andrew Sharpley, March 30, 2018). Therefore, we are comparing a composited sample with a grab sample collected (presumably) on the falling limb of the hydrograph. Nevertheless, the comparison indicates that ISCO and grab samples are not comparable.

Collection of representative storm samples requires specialized equipment and training, as well as time and money that may not have been available in the budget provided to BCRET. Manual sampling of storm water, including wading into the centroid of flow during storm events, can be difficult and dangerous. The bridge at BC6 is only about 3 feet above the water at low flow and may be submerged during many storms. Installation of a cableway and subsequent water sampling would solve this problem. There is no bridge at BC7 but Big Creek can be sampled about 0.6 river mile downstream at Highway 123; sampling from a highway bridge during inclement conditions presents its own set of safety problems.

The length of time I used for most trend analyses was 4 years. Analysis of water-quality trends for time periods of less than 5 years is not recommended (Schertz and others, 1991). However, this is a case where some exploratory analysis of data is warranted and specific efforts were taken to evaluate factors that might affect the validity of the trend analysis for a slightly truncated period of analysis. Nonetheless, the limitation of the data and associated results were considered. Variation in weather-related factors such as seasonal/annual precipitation, air temperature, and streamflow are sources confounding influences on water quality that can be reflected in water-quality trends (see figures 6-9 for streamflow and precipitation comparisons by year). Trend analysis (Spearman's rho) of 15-minute streamflow values at BC7 measured at the time of water-quality sampling at BC7 did not indicate a trend in streamflow ($p=0.43$) (fig. 6). Annual variation in streamflow (annual and streamflows less than 80 cubic feet per second—the 90th percentile of streamflows for base samples at BC7 (figs. 7 and 8) did not indicate trends in streamflow from 2015 through 2017. The annual precipitation at Harrison (approximately 24 miles north of Mt. Judea) was greatest in 2015 and least in 2016 but did not indicate a consistent trend in precipitation from 2014 through 2017 (fig. 9). Using values that compare differences of concurrently collected values between sites or watersheds (BC7 minus BC6 concentrations, for example) for trend analysis help to minimize effects of annual or seasonal influences of weather and streamflow on trends.

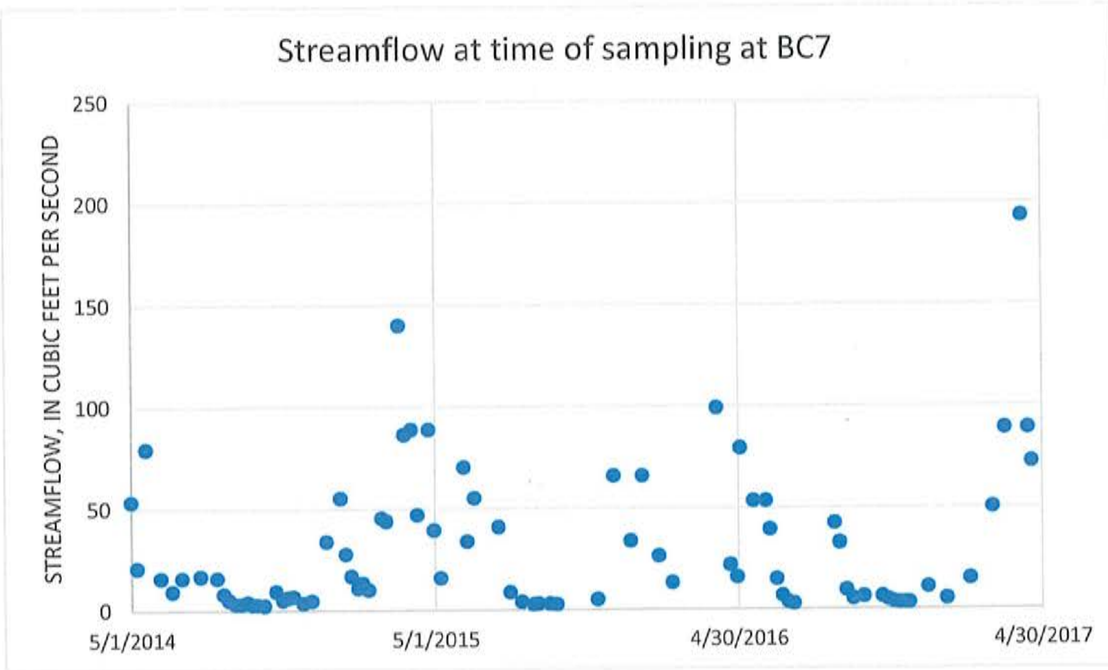


Figure 6. Streamflow values at USGS site 07055790 (colocated with BC7) at time of sampling at BC7. These are base samples only and do not include storm samples

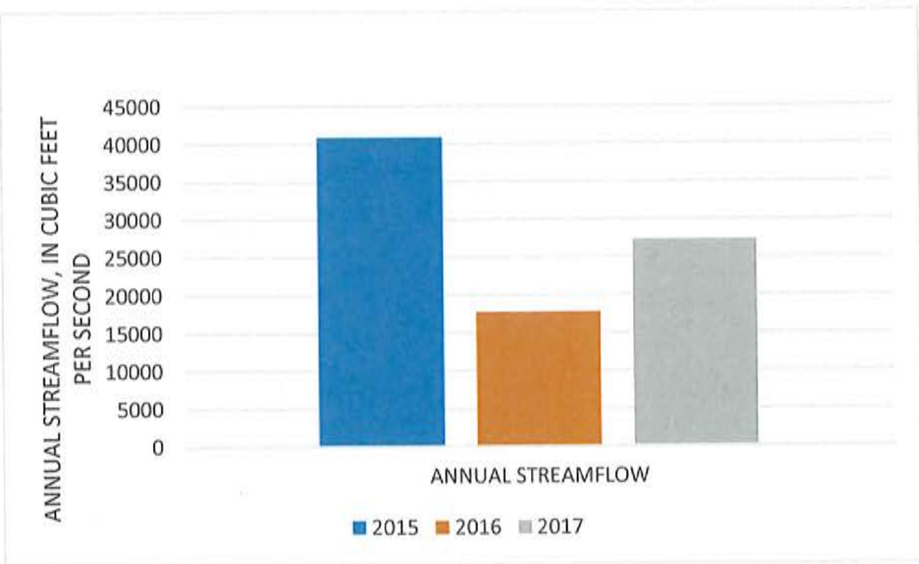


Figure 7. Annual mean streamflow at USGS site 07055790 (colocated with BC7)

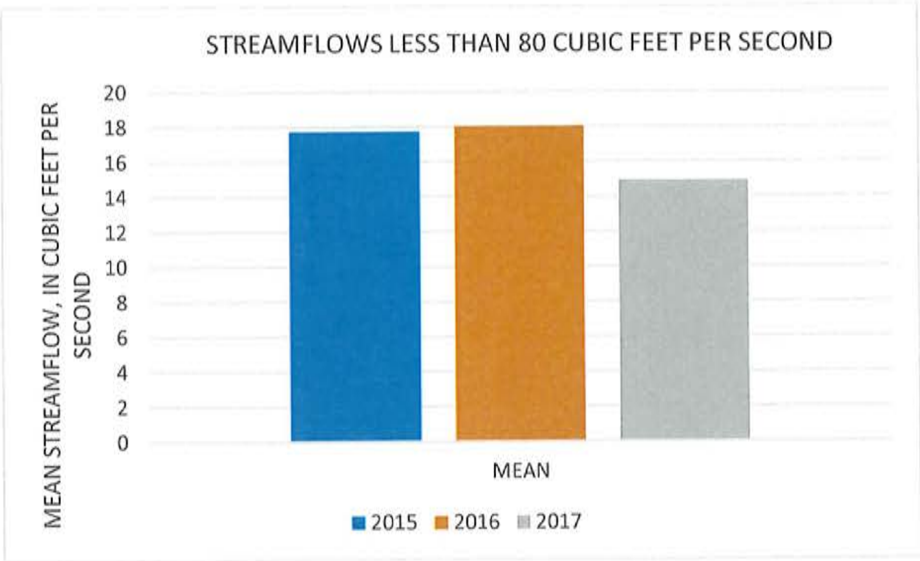


Figure 8. Annual mean streamflow when less than 80 cubic feet per second at USGS site 07055790 (colocated with BC7)

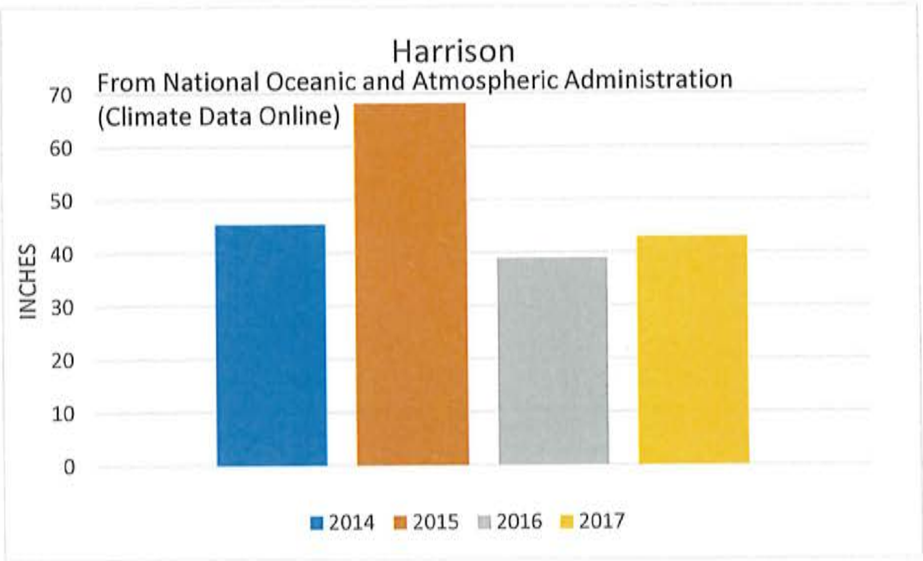


Figure 9. Annual precipitation for Harrison, Arkansas

Despite these limitations of the data, base flow water-quality data for Big Creek upstream and downstream of the farm and slurry receiving fields, and all data from a well near the hog barn, a spring on the east side of Big Creek, and two trench sites just downslope from two waste ponds suggest that water quality of Big Creek and groundwater of the Boone Formation is being impacted by operation of the hog farm. The hydrology and geology of the karstic Boone Formation, along with the water quality of Big Creek, suggests that the water quality and biota (the animal and plant life) of the Buffalo River and other parts of Buffalo National River potentially are being affected.

7.0 Water Quality of Big Creek

My analysis of water-quality data collected by BCRET focused on base flow conditions when streamflow is dominated by groundwater input. In my opinion, results from sites BC6 (upstream from C&H Hog Farms facilities and associated waste ponds and slurry spreading fields) and BC7 (downstream) indicates that the operation of the currently permitted Animal Waste Management System is having a negative effect on the water quality of Big Creek during base flow. Statistical analyses of the data indicated increasing trends in concentrations of chloride and some nutrients at BC7 when compared to BC6 concentrations.

Nitrogen (medians of 1,043 to 5,078 mg/L total nitrogen), phosphorus (medians of 114 to 5,070 mg/L total phosphorus), organic carbon (395 and 844 mg/L total organic carbon; Harbor Environmental and Safety, 2016), and chloride (medians of 338 to 532 mg/L) are among the contaminants found in hog waste (manure and urine) (median values from BCRET October-December 2016 Quarterly Report). Using multiple approaches, concentrations of several of these potential contaminants to Big Creek were analyzed to look for differences in concentrations and to look for temporal trends during the relatively short time that data have been collected by BCRET and others. Approaches included trend analysis at individual sites, trend analysis of differences between sites, comparisons of concentrations at sites, comparison of dissolved oxygen concentrations to associated factors and to water-quality standards, and analysis of inputs to Big Creek from the Nutrient Management Watershed pastures.

In addition to simply limiting my analysis to samples designated as "base/grab" within the BCRET-provided dataset, I examined the dataset to try to improve the accuracy of the designations. Based on information such as total suspended solids (TSS) concentrations, bacteria concentrations, and 15-minute streamflow data from the USGS site co-located with BCRET site BC7 I changed several base/storm designations for a revised dataset that I used for my data analysis.

During the first few months of sampling (which was before the first applications of hog waste slurry in January 2014) concentrations of most constituents from BC7 (downstream site) and BC6 (upstream site) generally were either higher downstream or were similar at both sites (figs. 10-12 for nitrate, total phosphorus, and dissolved organic carbon).

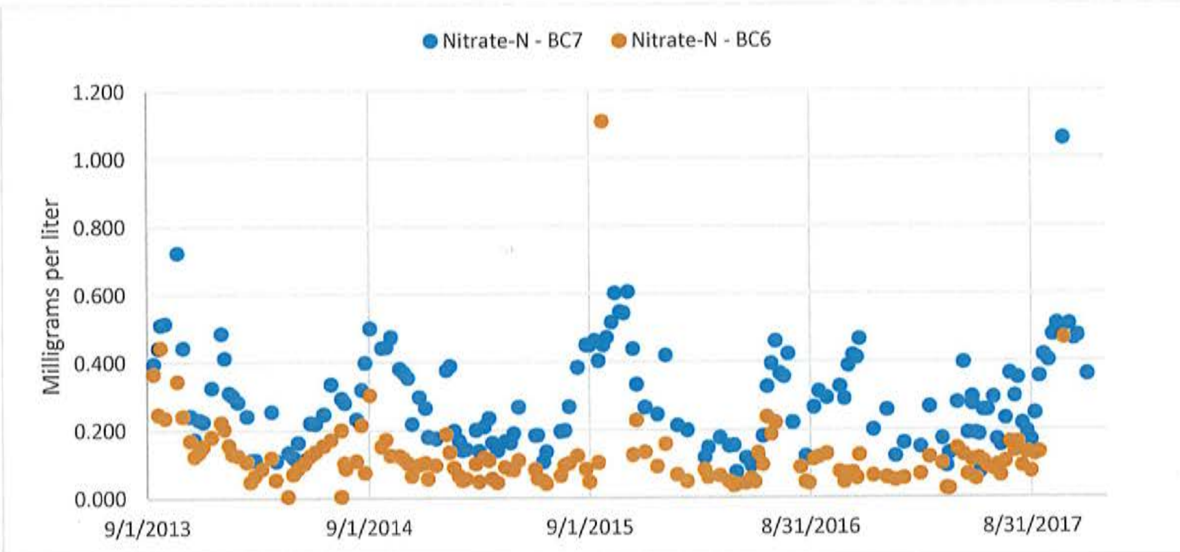


Figure 10. Nitrate concentrations from September 2013 through August 2017 at sites BC6 and BC7

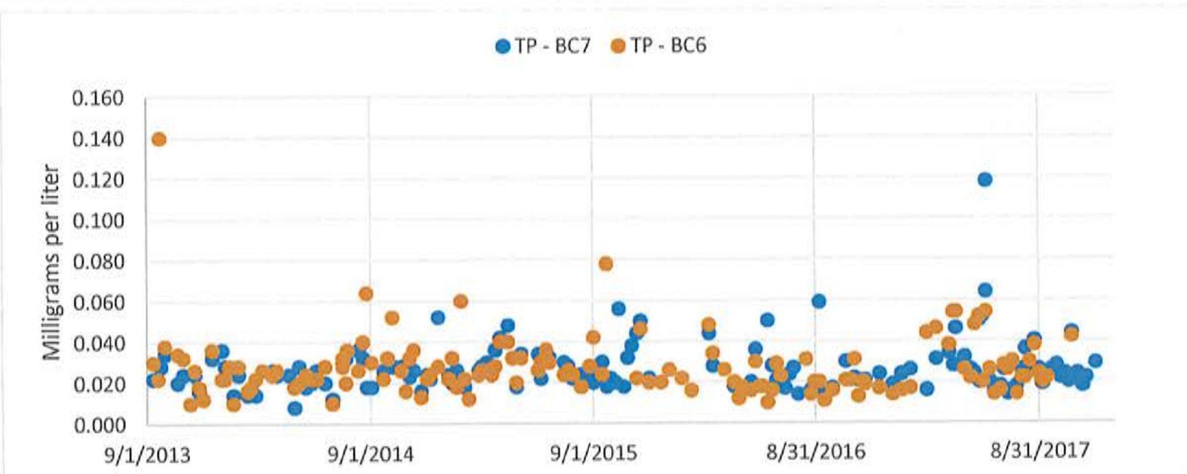


Figure 11. Total phosphorus concentrations from September 2013 through August 2017 at sites BC6 and BC7

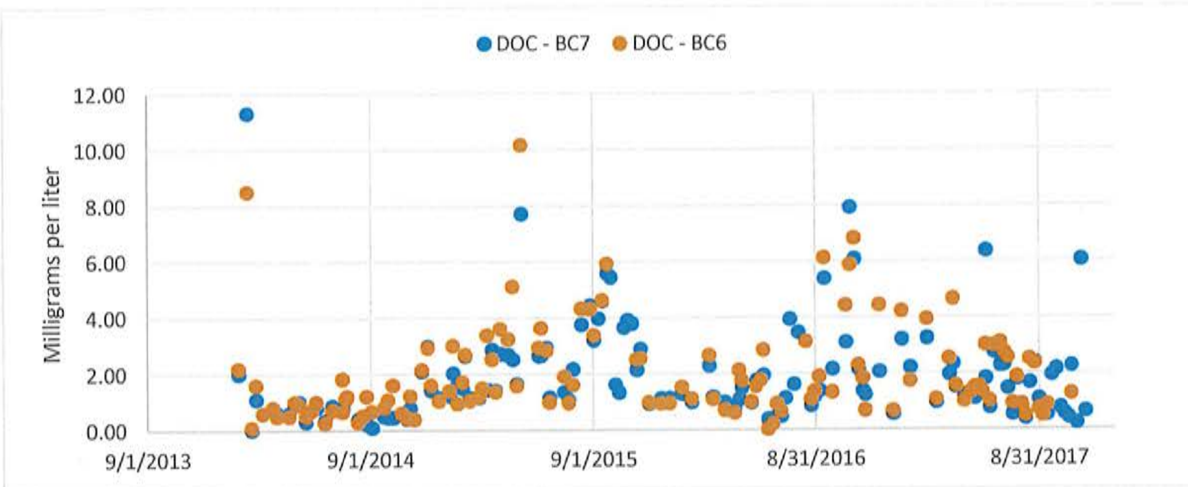


Figure 12. Dissolved organic carbon concentrations from September 2013 through August 2017 at sites BC6 and BC7

To evaluate changes during the period following the applications, a trends analysis of base flow data from January 2014 through December 2017 was conducted using Spearman's rank correlation of date with concentration (table 3). The first three months of data (October-December 2013) were not included because many of these constituents vary seasonally and inclusion of an uneven distribution of seasons could bias trend results. Statistical significance was set at $p<0.10$. This analysis indicates that nitrate (NO3) and chloride inputs were increasing between BC6 and BC7. For nitrate, concentrations were increasing at BC7 but were not increasing at BC6, indicating an increasing input from the part of the watershed between the two sites. For chloride, concentrations were decreasing at BC6, but were not decreasing at BC7, again indicating an increasing input from the part of the watershed between the two sites. Conversely it indicates that dissolved organic carbon (DOC), total suspended solids (TSS), and *E. coli* inputs were decreasing at BC7 relative to BC6. In either case, further analysis was warranted.

Table 3. Temporal trends for selected constituents at sites BC6 and B7

Temporal trends from January 2014 through December 2017

	BC6		BC7	
	Direction	p value	Direction	p value
NH3	Decreasing	<0.001	Decreasing	0.02
NO3	Not significant		Increasing	0.07
TN	Not significant		Not significant	
OP	Not significant		Not significant	
TP	Not significant		Not significant	
Chloride	Decreasing	0.03	Not significant	
DOC	Increasing	0.04	Not significant	

TSS	Increasing	0.05	Not significant
E. coli	Increasing	0.02	Not significant

To further analyze differences between the two sites, paired concentrations (those collected on the same day) at BC6 and BC7 were analyzed for temporal trends using the same methods used to analyze trends at the individual sites (table 4). Trends in BC7 concentration minus BC6 concentration (△ concentration) were analyzed. This approach has advantages over trend analysis for a single site because many factors that might confound trend analyses (for example, annual or seasonal variation in precipitation) are relatively consistent in effect on nearby sites (Dressing and Meals, 2005). Total nitrogen (TN), dissolved phosphorus (OP), and chloride △ concentrations increased between the two sites from January 2014 through December 2017 indicating increasing inputs of these constituents between the two sites. The area between the two sites is known as the Nutrient Management Watershed.

Table 4. Temporal trends in the difference between concentrations at sites BC6 and B7 for selected constituents

Temporal trends from January 2014 through December 2017

	BC7 minus BC6 concentration	
	Direction	p value
NH3	Not significant	
NO3	Not significant	
TN	Increasing	0.095
OP	Increasing	0.091
TP	Not significant	
Chloride	Increasing	0.04
DOC	Not significant	
TSS	Not significant	
E. coli	Not significant	

To isolate the response of <u>pasture</u> base flow discharge from the Nutrient Management Watershed (the area downstream of BC6 and upstream from BC7 where hog waste is surface applied to pastures, fig. 13), estimates of the yield of nitrate, dissolved phosphorus, and other constituents from pasture were calculated (see Appendix B for detailed methods). The calculations used water-quality, streamflow, land use, and watershed size data from BC6, BC7, Buffalo River, Richland Creek, and Beech Creek.

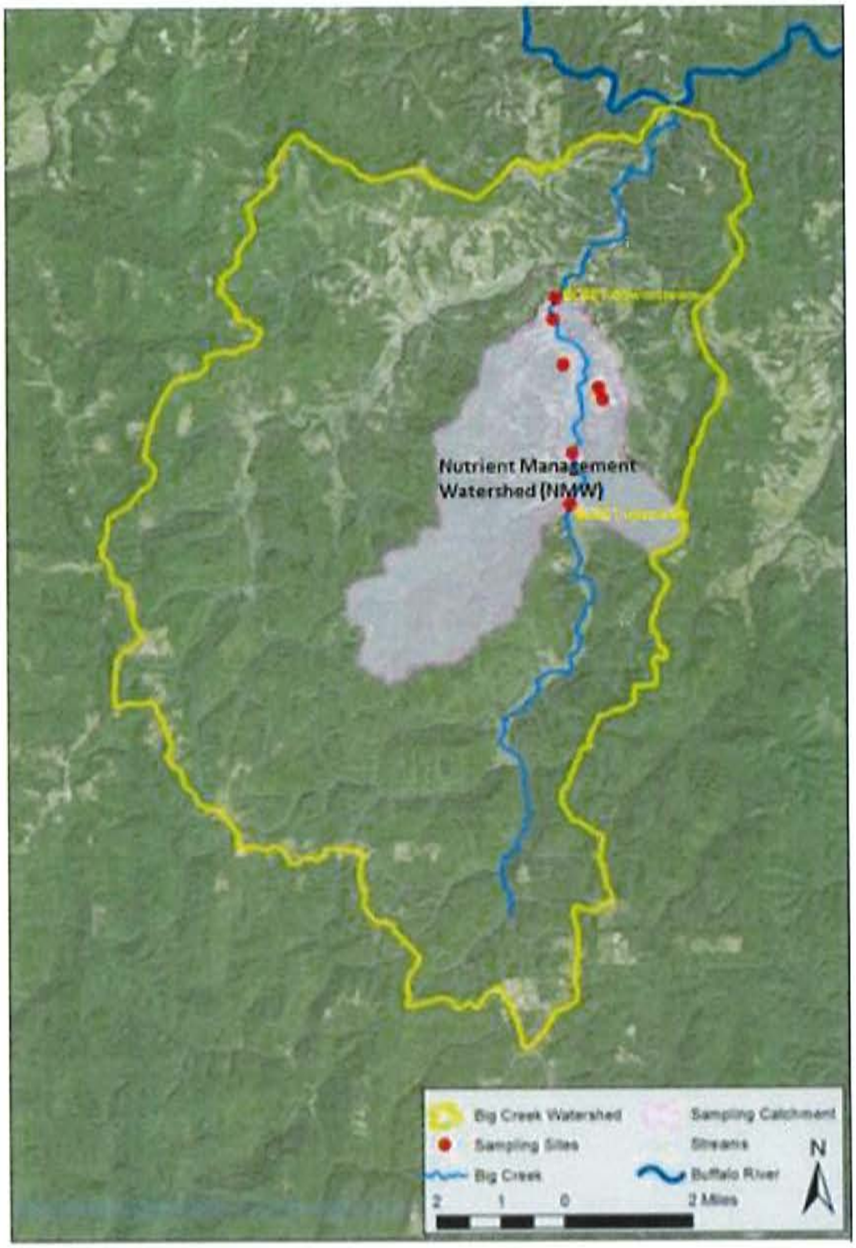


Figure 13. Location of Nutrient Management Watershed (purple), BC6 (upstream), and BC7 (downstream). Modified from BCRET October-December 2014 Quarterly Report.

To estimate the flux (an instantaneous load, calculated as the product of the concentration of an individual sample and the 15-minute streamflow), yield (calculated as the flux divided by the drainage area), and concentrations for waters flowing from the pasture areas of the BC6 watershed and the Nutrient Management Watershed, a multi-step process was used to examine nitrogen, phosphorus, dissolved organic carbon, chloride and *E. coli* data. The process included estimation of streamflow at BC6 (which by definition introduces errors in subsequent calculations not introduced by methods focused solely on concentration differences), estimation of concentrations in water from forests, and use of two-component mixing models. The primary goal of this process was to estimate the yield (mass per second per square mile) and concentration of nitrate and total phosphorus from areas of pasture land use in the Nutrient Management Watershed and the BC6 watershed. The individual pasture yields from the BC6 and Nutrient Management Watershed watersheds were compared using the Wilcoxon Signed Rank Test and trends were analyzed using Spearman's rank correlation. For trend analysis the data were restricted to October 1, 2014 to September 30, 2017 to avoid a bias caused by including data that do not represent multiples of 12-month periods. Many water-quality constituents naturally vary from one season to another, so it would not be proper to begin a trend analysis period at a time when concentrations are naturally lower and end the analysis period at a time when concentrations are naturally higher. The trend analysis was performed on the difference (△ yield, Nutrient Management Watershed yield minus BC6 watershed yield) between the two watersheds. This process is described in more detail in Appendix B.

Derived (calculated) concentrations of nitrate, total nitrogen, and chloride from the Nutrient Management Watershed pastures were substantially higher than concentrations from the BC6 watershed pastures. The mean nitrate concentration of water discharging from pasture land in the NMW watershed was 2.2 times the concentration of water discharging from pasture land in the BC6 watershed (fig.14). The mean concentration of total nitrogen from pasture land in the Nutrient Management Watershed was 2.5 times that of the mean concentration from pasture land in the BC6 watershed and the mean concentration of chloride was approximately 1.4 times higher than the mean concentration from pasture land in the BC6 watershed (not shown).

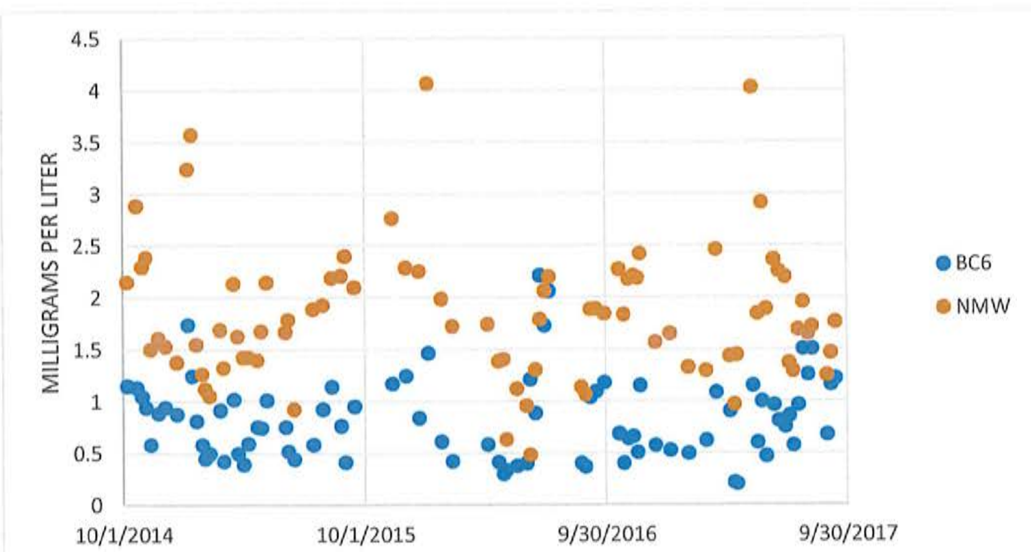


Figure 14. Derived concentrations of nitrate coming from pasture land in the BC6 and NMW watersheds

Trend analyses of concentrations were performed for the three constituents with significantly higher yields from the NMW watershed (table 5). No trends (upward or downward) were detected in concentrations of nitrate or chloride from pastures in either watershed or in the differences (NMW watershed minus BC6 watershed) between concentrations for pastures in the two watersheds (not shown). Statistically significant downward trends in total nitrogen were detected in the NMW pasture concentration (p=0.04, not shown) and the difference between NMW and BC6 watershed concentrations (p=0.09; not shown).

The derived yield (milligrams per second per square mile) of nitrate from pasture land in the Nutrient Management Watershed was almost three times that of the yield from pasture land in the BC6 watershed (fig. 15). The yields were significantly different (Wilcoxon signed rank test, p<0.001) than the yield from pasture land in the BC6 watershed yield (table 5). Total nitrogen and chloride yields were significantly higher from the NMW watershed pasture than from the BC watershed pasture (table 5). No trends were detected other than a downward trend in the difference between total nitrogen NMW pasture yields and BC6 watershed pasture yields (table 5).

No trends (upward or downward) were detected in yields of nitrate from pastures in either watershed or in the differences (NMW watershed minus BC6 watershed) between yields for pastures in the two watersheds (table 5).

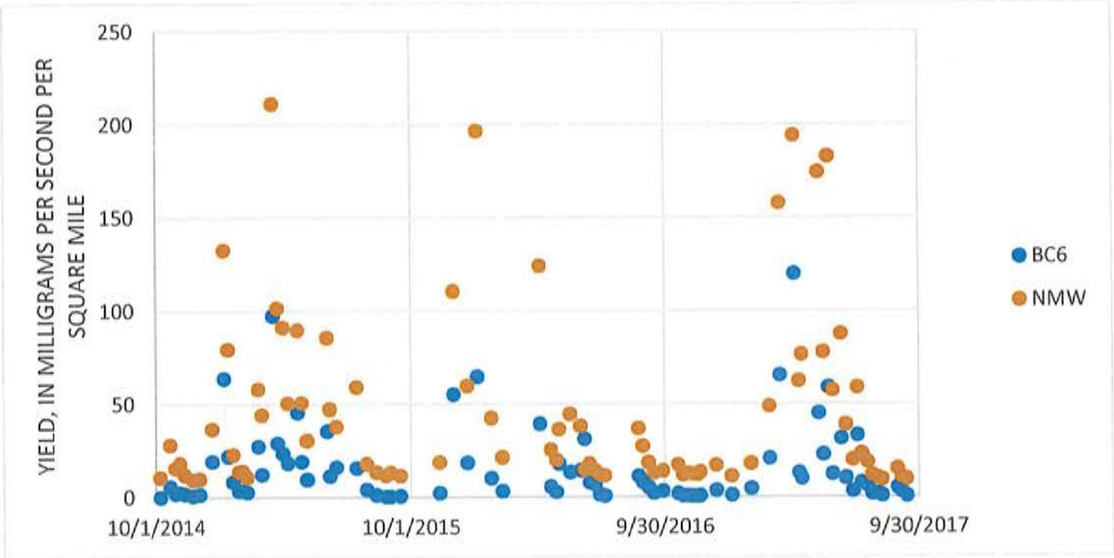


Figure 15. Derived yields of nitrate coming from pasture land in the BC6 and NMW watersheds

Table 5. Statistical analysis of difference between yields from pastures at BC6 and NMW watersheds and of trends in yields from pastures in the NMW watershed and the difference in yields from pastures in the BC6 and NMW watersheds

	Wilcoxon two-tailed test of differences between yields	NMW watershed yields	Spearman correlation	NMW minus BC6 yields	Spearman correlation
	p-value	Trend direction	p-value	Trend direction	p-value
Diss. phosphorus	NS	Not tested**	Not tested*	Not tested**	Not tested**
Total phosphorus	NS	Not tested**	Not tested*	Not tested**	Not tested**
Ammonia	NS	Not tested**	Not tested*	Not tested**	Not tested**
Nitrate	<0.001***	NS	NS	NS	NS
Total nitrogen	<0.001***	NS	NS	Decreasing	0.04
Diss. organic carbon	NS	Not tested**	Not tested*	Not tested**	Not tested**
Chloride	<0.001***	NS	NS	NS	NS
E. coli	NS	Not tested**	Not tested*	Not tested**	Not tested**

NS is not significant (at p=0.10)

**Trends were not tested because the yields for BC6 watershed were higher than for NMW watershed

***Higher for the NMW watershed

The significantly higher concentrations and yields from the pasture land in the NMW watershed and the lack of any temporal trends suggests one of three scenarios. One--agricultural practices preceding the operation of C&H Hog Farms in the NMW watershed have resulted in a source of nitrate that is greater than the source in the BC6 watershed. Two—the application of hog waste has resulted in a rapid (within the 9 months from January to October 2014) and substantial increase in nitrate concentrations and yields but that initial increase has not continued to increase in magnitude since October 2014. Or three—some combination of the first two scenarios.

Also, there are inherent errors in using watershed ratios to estimate the discharges from BC6, the BC6 watershed, and the pasture and forest components of the discharge from the BC6 and NMW watersheds. These errors would affect the derived concentrations and yields from the pasture and forest of the BC6 and NMW watersheds.

Derived concentrations and yields from May 2014 (the earliest date that NMW concentrations and yields could be calculated because of absence of flow data prior to May 2014) were visually compared to the later data and no difference in values was apparent. This makes the second scenario less likely.

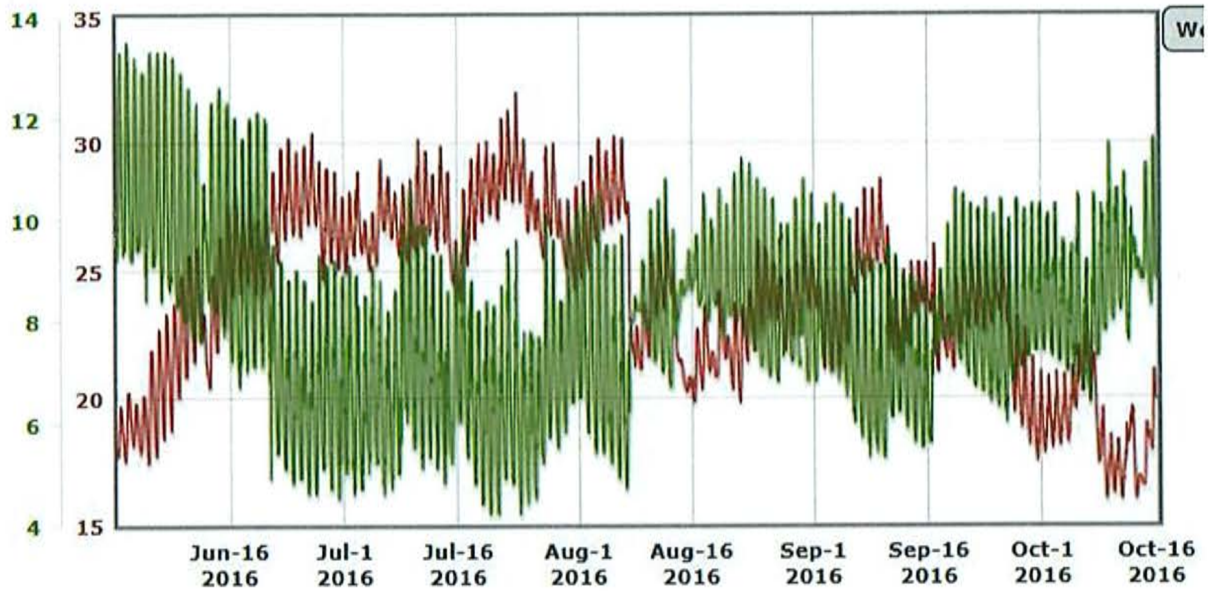
Yields and concentrations for the BC6 and NMW watersheds also were derived for total phosphorus, dissolved phosphorus, ammonia, dissolved organic carbon, and *E. coli.* Concentrations and yields of these constituents from the BC6 watershed were higher than from the NMW watershed indicating that the NMW watershed pastures are contributing less of these constituents than BC6 watershed pastures are contributing. Therefore, additional statistical analyses were not performed for these constituents (table 5). **It is important to remember that these analyses are based only on base samples, those not associated with storm events, and that phosphorus, total nitrogen, sediment, and *E. coli* would be expected to be transported primarily in the storm runoff.**

In my opinion, the frequency and seasonal persistence of dissolved oxygen concentrations of Big Creek at Carver that are often substantially below the state standard may be causing detrimental effects on aquatic species and fish and macroinvertebrate (aquatic insects, etc.) communities of Big Creek and the Buffalo River. The proximity to the Buffalo River and anti-degradation policy concerns are another immediate concern.

The U.S. Geological Survey operated a streamgage equipped with a multi-parameter (pH, water temperature, specific conductance, and dissolved oxygen) probe on Big Creek at Carver from June 2014 through May 2017. Dissolved oxygen concentrations frequently did not meet the dissolved oxygen water-quality standard (6 mg/L) in each year and the lower part of Big Creek has been placed on the 2018 draft list of impaired Arkansas waters because of the low dissolved oxygen concentrations (https://www.adeq.state.ar.us/water/planning/integrated/303d/list.aspx). The standard was not met on 60 days in 2014, 61 days in 2015, and 52 days in 2016. The minimum concentrations were 4.0, 4.4, and 4.2 mg/L in 2014, 2015, and 2016, respectively. In 2014 and 2015 the concentrations less than 6 mg/L first occurred in early to late August and persisted into mid-September. In 2016 concentrations less than 6 mg/L first occurred in late June and persisted into early August and then recurred from early September until mid-September. These low dissolved oxygen concentrations seemed to occur when water temperatures warmed to approximately 26° - 29° Celsius (79° to 84° Fahrenheit) and streamflow decreased to 4 to 10 ft^3/sec. (see figs. 16-17). These periods were usually preceded by increases in specific conductance to about 240 to 250 microsiemens per centimeter. Increases of dissolved oxygen concentrations during and after the periods of low concentration were typified by increases in streamflow and/or decreases in water temperature.

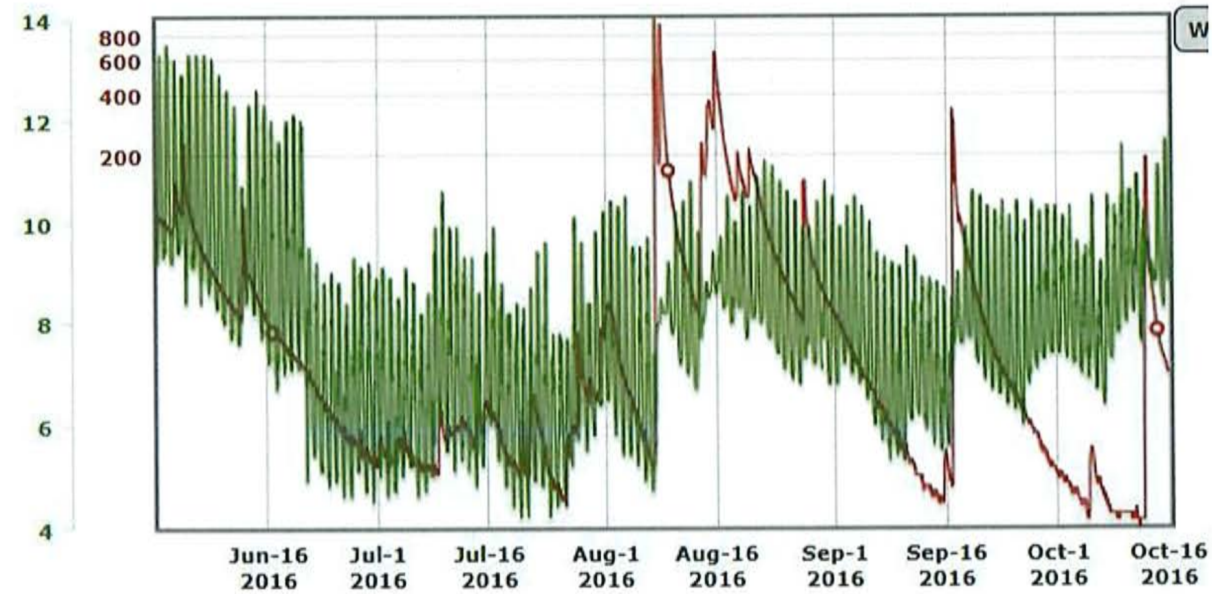
The combination of low streamflow and high specific conductance suggests that dominance of groundwater in the streamflow followed by summer warming is a factor in the low dissolved oxygen concentrations. I am not aware of data for dissolved oxygen concentrations in karst groundwater reaching streams as diffuse flow but the concentrations could be susceptible to presence of contaminants (organic carbon or organic nitrogen) that would require oxygen during bacterial decomposition and respiration. Reareation rates in groundwater could be lower than in streams and there is no photosynthesis in groundwater to add oxygen to the water. Dissolved oxygen concentrations for three springs in the Buffalo National River water-quality database average 9.2 mg/L, so dissolved oxygen concentrations certainly can be protective of aquatic life.

This is another example of how important good quality groundwater is to Ozark ecosystems. When groundwater (which in degraded conditions, or where rearation rates are low, could be low in dissolved oxygen) is contaminated by nutrients that can stimulate algal growth and respiration and by contamination by organic carbon and organic nitrogen that can stimulate bacterial decomposition is discharged to surface water, the result can be depressed dissolved oxygen concentrations. Algal respiration and bacterial decomposition both decrease dissolved oxygen concentrations.



Green is dissolved oxygen, red is water temperature

Figure 16. Dissolved oxygen concentrations and water temperature June through October 2016 at Big Creek near Carver



Green is dissolved oxygen, red is streamflow

Figure 17. Dissolved oxygen concentrations and streamflow June through October 2016 at Big Creek near Carver

The magnitude of the departure, in concentration and persistence, of the dissolved oxygen concentrations from the state water-quality standard should be of consideration under the Regulation 2 anti-degradation policy as it pertains to the Buffalo River because it is an Extraordinary Resource Water and Natural and Scenic Waterway. The Buffalo River is about 0.5 river mile downstream from the Big Creek near Carver and potentially closer than that for a groundwater connection. During periods of low flow, which is when dissolved oxygen concentrations at Carver are lowest, as much as one-third of flow in the Buffalo River is contributed by Big Creek and groundwater flowing into the Buffalo River (Moix and Galloway, 2005). Both of these sources could be affected by the low dissolved oxygen concentrations at Carver. The anti-degradation policy states that "those uses and water quality for which the outstanding waterbody was designated shall be protected by (1) water quality controls, (2) maintenance of natural flow regime, (3) protection of instream habitat, and (4) encouragement of land management practices protective of the watershed."

8.0 Water Quality of Ephemeral Stream (BC4)-A Tributary of Big Creek

In my opinion, increasing trends in some nutrients, dissolved organic carbon, and E. coli in samples from site BC4 (Ephemeral Stream) indicate that inputs of these constituents to Big Creek are increasing and potentially affecting water quality of Big Creek near the hog farms and downstream from the confluence of this stream and Big Creek. If concentrations are increasing in base flow samples it is likely that concentrations in storm water also are increasing—and concentrations are almost certainly higher in the storm water than in base flow. Temporal trends in BCRET-designated base flow water-quality data from March 2014 through March 2017 were assessed. Statistical analysis was performed on all samples that were identified as "base,grab" samples by BCRET. To further clarify, an ephemeral stream flows only in direct response to precipitation yet there were 48 "base" samples in addition to those designated as storm samples. The existence of the base samples indicates that the stream is not an ephemeral stream, but rather an intermittent stream with a groundwater flow component. These 48 "base,grab" samples were analyzed for BC4 (variously referred to by BCRET as Culvert or Ephemeral Stream). Statistically significant increasing trends in nitrate, total nitrogen, dissolved phosphorus, dissolved organic carbon, and *E. coli* bacteria were detected (table 6 and figs. 18-21). These results suggest that groundwater and runoff from the watershed area (which includes the hog barns and waste ponds) are being affected by C&H Hog Farms operations. The watershed area of BC4 is approximately 0.17 square mile and is approximately 64 percent forest (delineated using the U.S. Geological Survey StreamStats application; https://streamstats.usgs.gov/ss/).

Table 6. Temporal trends in selected constituents from site BC4

Temporal trends from March 26, 2014 through March 16, 2017

	BC4 concentration trends	
	Direction	p value
NH3	Not significant	
NO3	Increasing	0.002
TN	Increasing	<0.001
OP	Increasing	0.011
TP	Not significant	
Chloride	Insufficient data	
DOC	Increasing	0.01
TSS	Not significant	
E. coli	Increasing	0.08

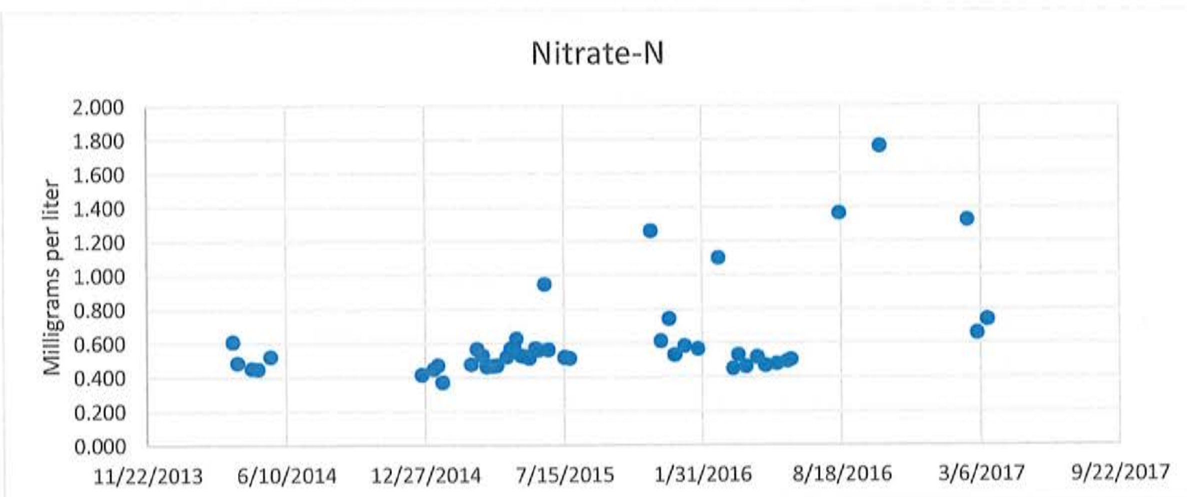


Figure 18. Nitrate concentrations at BC4 (Ephemeral Stream) from January 2014 through March 2017

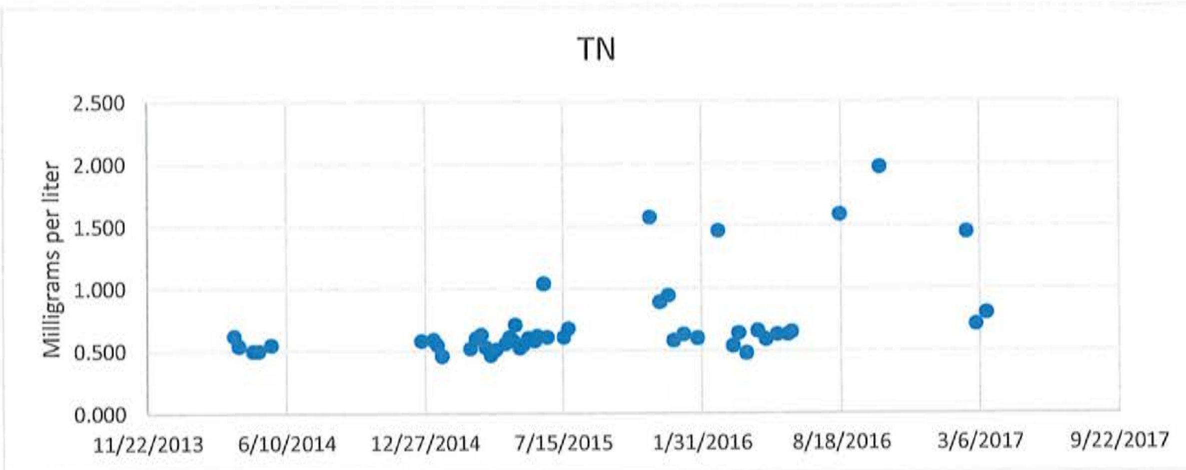


Figure 19. Total nitrogen concentrations at BC4 (Ephemeral Stream) from January 2014 through March 2017

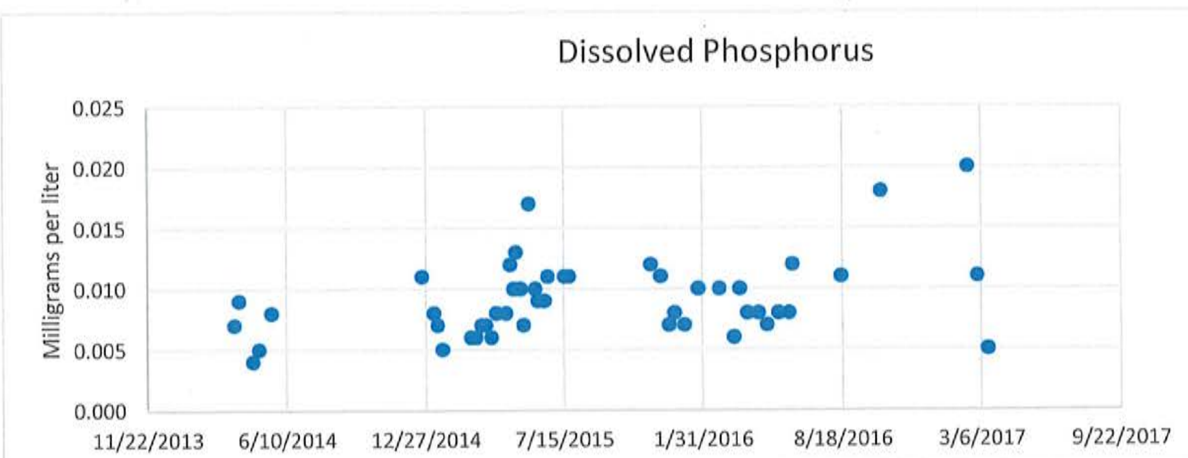


Figure 20. Dissolved phosphorus concentrations at BC4 (Ephemeral Stream) from January 2014 through March 2017

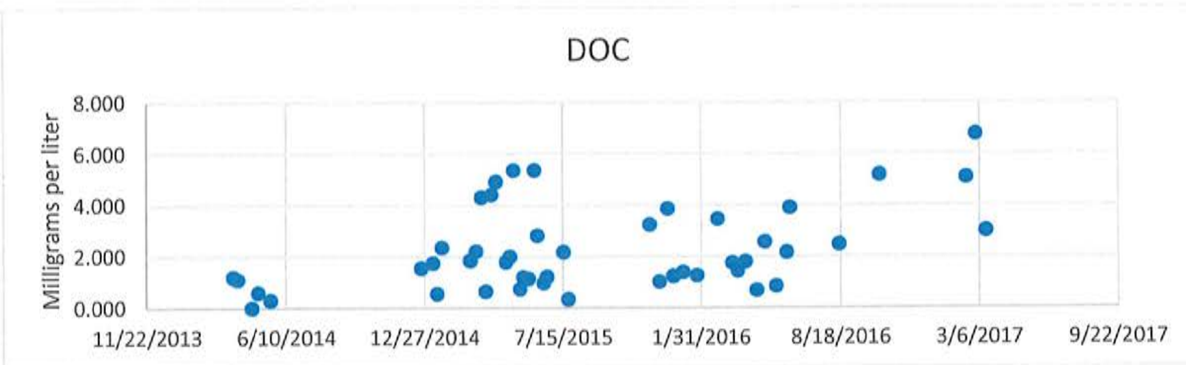


Figure 21. Dissolved organic carbon concentrations at BC4 (Ephemeral Stream) from January 2014 through March 2017

9.0 Aquatic Biology

In my opinion, comparison of concentrations of total nitrogen and total phosphorus at BC7 to biological thresholds for nutrients in wadeable Ozark streams indicates that existing concentrations are approaching (total nitrogen) or have exceeded (total phosphorus) concentrations affecting periphyton (attached algae), macroinvertebrate (aquatic insects, etc.), and fish communities.

Justus and others (2009) conducted a study of the relation of summer (July through August) base flow nutrient concentrations and periphyton, macroinvertebrate, and fish communities of 30 wadeable Ozark streams spanning a range of nutrient concentrations. This study's seasonal time period, water quality sampling methods, geographic location, and stream size are all very comparable to information collected at Big Creek (Justus and others, 2009). The streams also were similar in size to Big Creek, were in watersheds without substantial urban influence, and were sampled consistently within a multi-week period.

Biological indexes responsive to nutrient concentrations were developed for each of the three communities. Higher index values are indicative of biological communities that are more likely to be representative of least-disturbed sites with lower nutrient concentrations. Justus and others (2009) presented relations between the indices and concentrations of total nitrogen and total phosphorus (fig. 22); I have modified the figure by adding blue lines that approximate interpreted thresholds (my interpretation), a green line that shows the piecewise regression breakpoint (threshold) for total nitrogen (only), and orange lines that indicate the June 15 through August 31 means of total nitrogen and total phosphorus at BC7. The piecewise regression, which looks for a breakpoint between two linear parts of a relation, was performed using software available at https://www.waterlog.info/segreg.htm. The mean BC7 total nitrogen concentration is approximately one-third to one-half of the nitrogen thresholds, indicating that Big Creek biological communities are not being adversely affected by the existing total nitrogen concentrations. The mean BC7 total phosphorus concentration is nearly double the interpreted phosphorus threshold, indicating that the biological communities are being adversely affected by the existing phosphorus concentrations.

Dissolved phosphorus concentrations were increasing at Ephemeral Stream and at BC7 (relative to BC6, i.e. BC7 minus BC6 concentrations). Trend analyses indicate increasing concentrations of ammonia, nitrate, and total nitrogen at one or more of several sampling sites (BC7, Ephemeral Stream, and House Well). Widespread increases in these nutrients indicate that any impact on aquatic communities will continue to worsen.

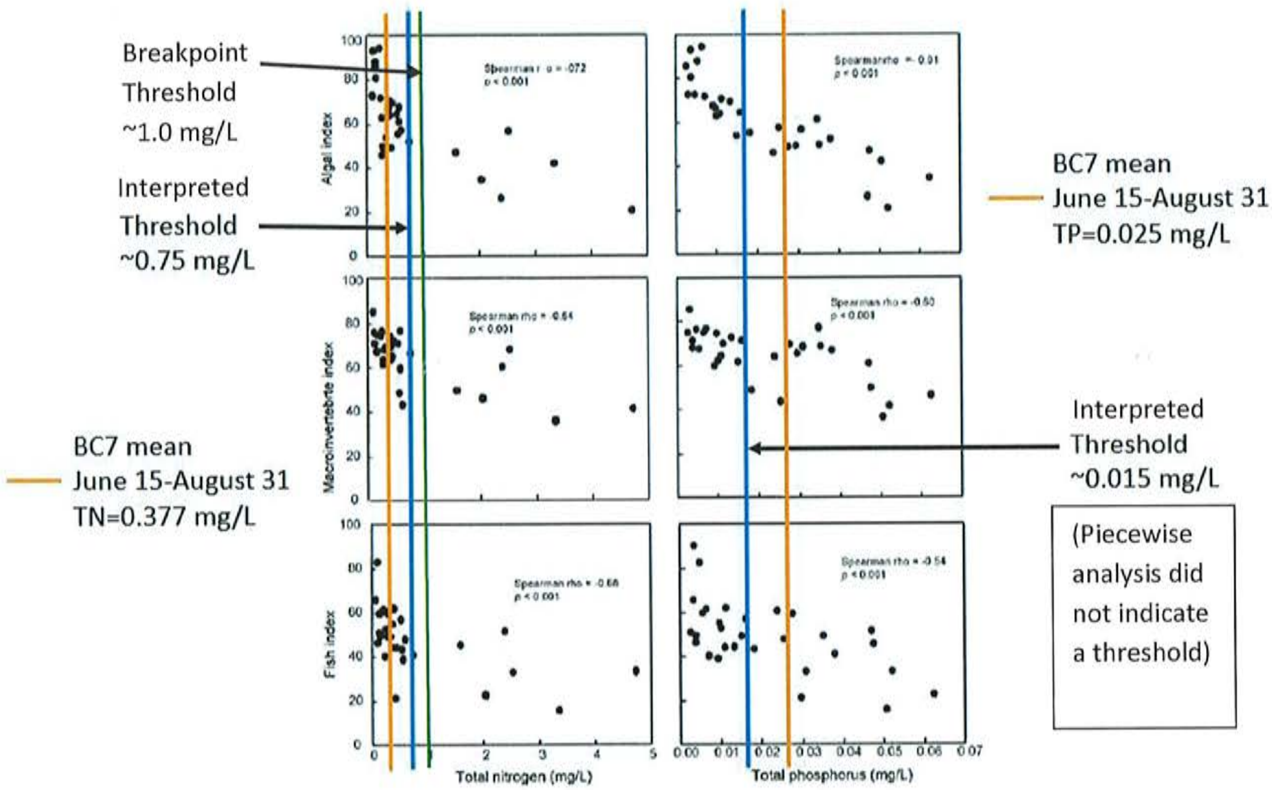


Figure 22. Relations of Ozark periphyton, macroinvertebrate, and fish index values with associated concentrations of total nitrogen and total phosphorus and comparison to BC7 mean total nitrogen and total phosphorus concentrations (modified from Justus and others, 2009)

10.0 Water Quality of Groundwater

Base samples from BC6, BC7, and Ephemeral Stream are composed largely of groundwater effluent, and so my previously described analyses of the data from these sites indirectly addresses groundwater quality. BCRET has directly sampled groundwater at two locations—the House Well located about 330 feet north of the waste ponds and a spring located about 0.8 mile southeast of the waste ponds on the opposite side (east side) of Big Creek. The well is drilled 325 feet through the Boone Formation (cherty limestone), Fernvale/Plattin Limestones, and into the Everton Formation (limestone). During the drilling of the well, water-bearing intervals were encountered at depths of 145 feet in the Boone Formation and 265 feet and 285 feet in the Everton Formation (based on driller's log by Arnold Well Drilling and Pump Service and information in Braden and Ausbrooks, 2003).

Because of a change in the sample collection point and a modification of the sampling protocol (see BCRET October-December 2015 Quarterly Report for details), samples collected from the House Well prior to September 30, 2015 were not included in my analyses. This is unfortunate because this resulted in 29 months of data (at most, less for some constituents) at the House Well. Plots of constituent concentrations against time did not indicate consistent seasonal patterns so the entire period after September 29, 2015 was analyzed for temporal trends.

In my opinion the increasing trends in concentrations of three nitrogen constituents in samples from the BCRET House Well site indicate contamination of the shallow groundwater aquifer. The steadily increasing pattern observed for several parameters indicates a constant input to the local aquifer feeding the well. Results at BC7 also indicate a strong correlation between increasing nitrate concentrations during low flow periods characterized by increased groundwater discharge.

Ammonia, nitrate, and total nitrogen concentrations all increased significantly (table 7 and figs. 23-25) in samples from the House Well. *E. coli* concentrations (table 7 and fig. 25) and specific conductance values decreases significantly. Most *E. coli* concentrations were less than 2 colonies per 100 milliliters—usually reported as 1 or <1, so the actual change in concentration was very small. The decrease in specific conductance values may, at least in part, be due to changes around the well caused by pulverized limestone produced during the drilling of the House Well. The increasing trends in concentrations of three forms of nitrogen dominated by dissolved phases suggest that dissolved material may be leaching into the groundwater while suspended material is not reaching the groundwater.

Table 7. Temporal trends in selected constituents from the House Well

Temporal trends from September 2015 through February 2018

	House Well concentration trends	
	Direction	p value
NH3	Increasing	<0.001
NO3	Increasing	<0.001
TN	Increasing	<0.001
OP	Not significant	
TP	Not significant	
Chloride	Not significant	
DOC	Not significant	
TSS	Not significant	
E. coli	Decreasing	<0.001
Specific conductance	Decreasing	<0.001

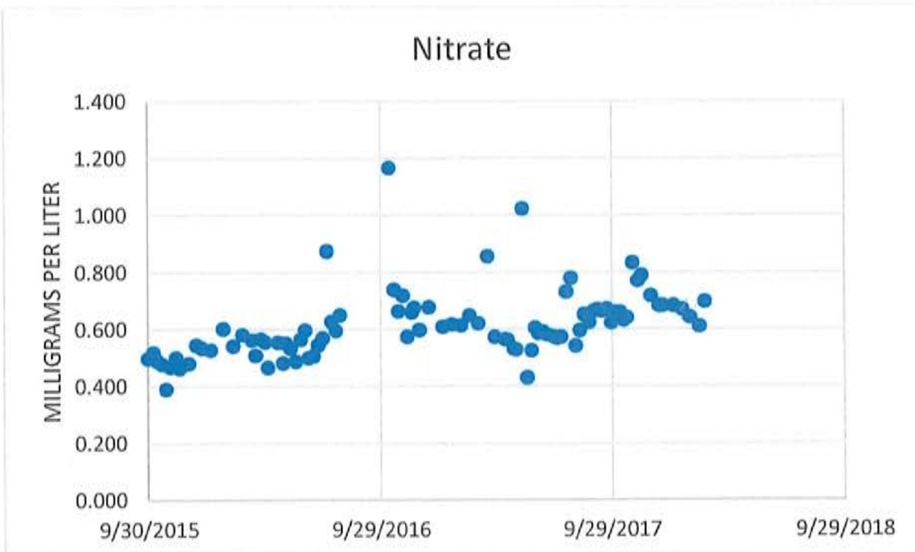


Figure 23. Nitrate concentrations at House Well from September 2015 through February 2018

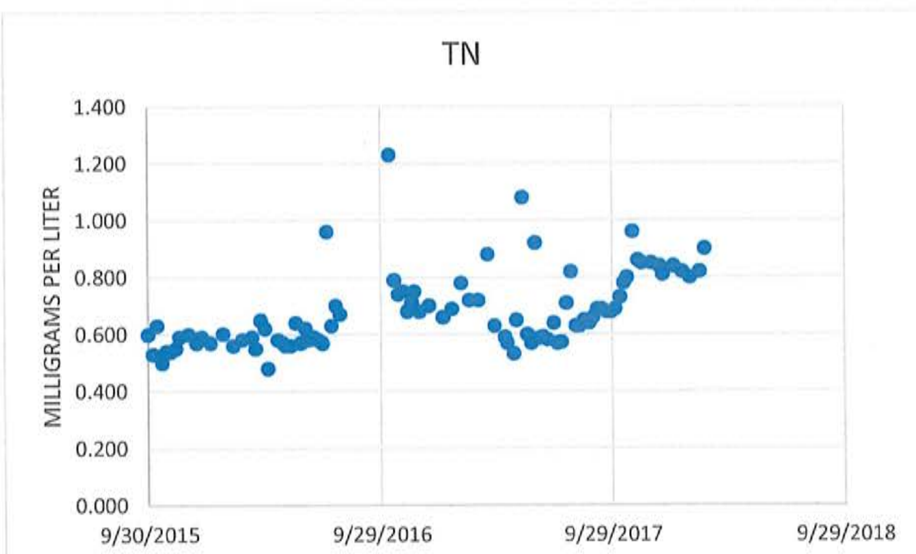


Figure 24. Total nitrogen concentrations at House Well from September 2015 through February 2018

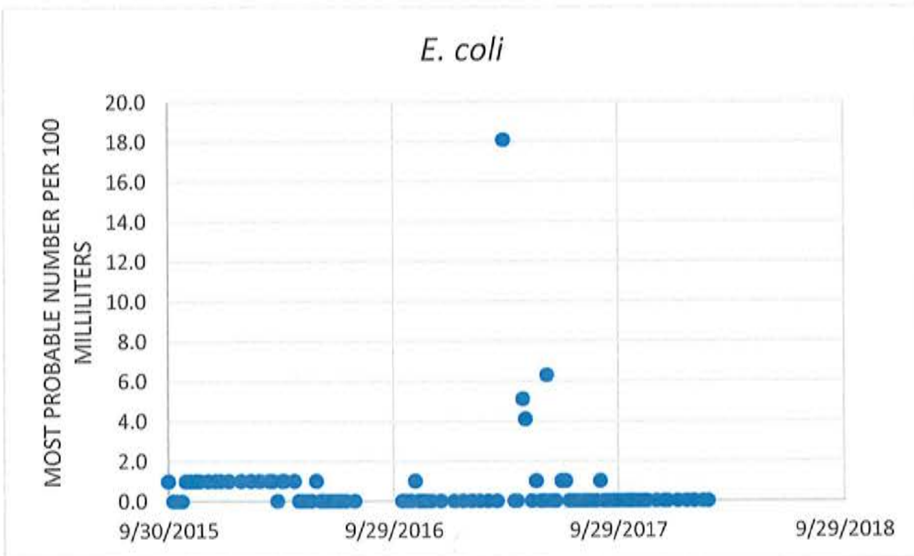


Figure 25. *E. coli* concentrations at House Well from September 2015 through February 2018

The spring (site BC5) outlet also is in the Boone Formation, however, without a dye tracing study, the area that contributes to the spring cannot be determined. Nevertheless, there are some substantial differences between the water quality of the well and the spring—or at least between the water-quality data values, because I could not determine which, if any, samples from the spring were associated with storm flow and so should not be included in the analysis. Total phosphorus, dissolved organic carbon, and total suspended solids concentrations are higher for the spring (means of 0.07, 5.2, and 33 mg/L, respectively) than for the House Well (means of 0.02 and 2.1, and 0.4 mg/L, respectively). *E. coli* concentrations also are higher for the spring (mean of 563 most probable number of colonies per 100 milliliters) than for the House Well (mean of 0.6 colonies). Total nitrogen means for the House Well (0.68 mg/L) and the spring (0.65 mg/L) are very similar, but nitrate means are higher for the House Well (0.61 mg/l versus 0.43 mg/L). Flow volumes associated with samples from the spring are not reported in the BCRET database, but it is likely that the highest of the total phosphorus, dissolved organic carbon, total suspended solids, and *E. coli* values are associated with high flows (and are probably storm-related) from the spring. Data about the flow volumes from the spring, the lag time between local precipitation and flow volumes, and dye tracing would provide insight into recharge area for this spring.

Lack of information about flow volumes makes it difficult to interpret the concentration data from the spring—or to interpret how the spring data relate and compare to the well data. I have included all data in my trend analyses and do not know how much, if any, the results are influenced by high flows. Except for total phosphorus, all nutrient concentrations decreased significantly (table 8 and fig. 26). Chloride, dissolved organic carbon, and total suspended solids increased significantly (table 8 and figs. 27 and 28).

Table 8. Temporal trends in selected constituents from the spring

Temporal trends from September 2014 through September 2017

	Spring concentration trends	
	Direction	p value
NH3	Decreasing	0.096
NO3	Decreasing	0.003
TN	Decreasing	0.007
OP	Decreasing	0.07
TP	Not significant	
Chloride	Increasing	0.03
DOC	Increasing	0.003
TSS	Increasing	0.001
E. coli	Not significant	

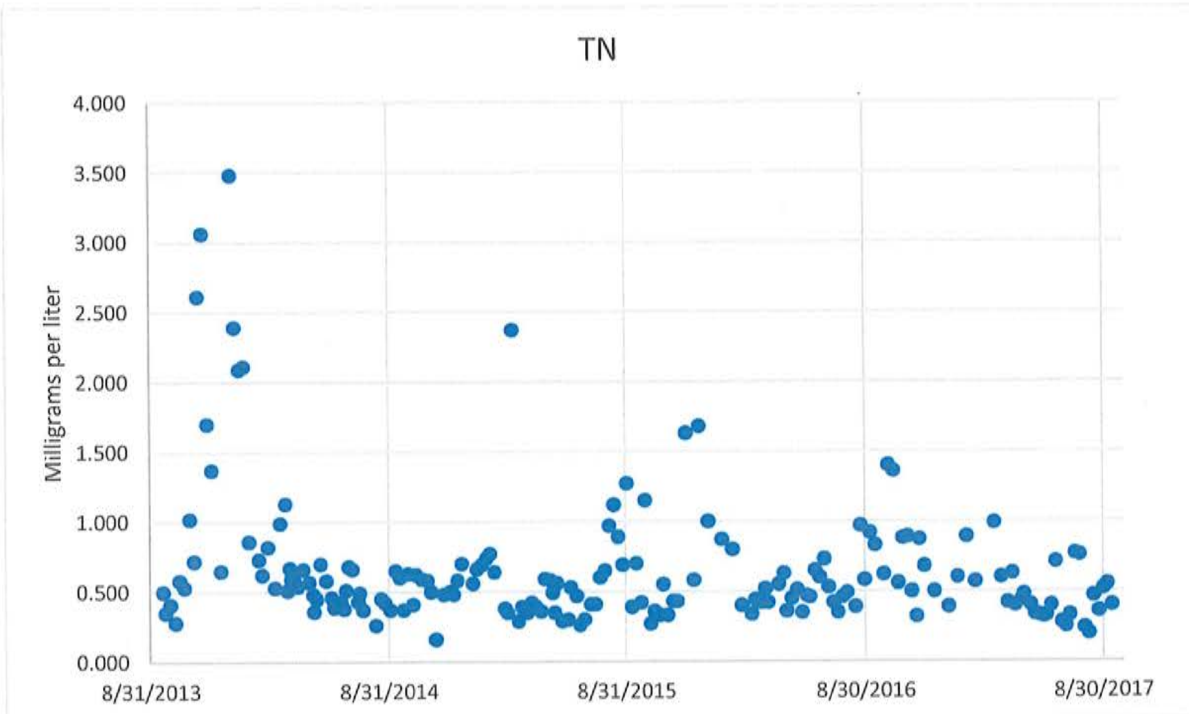


Figure 26. Nitrate concentrations at spring from September 2013 through August 2017

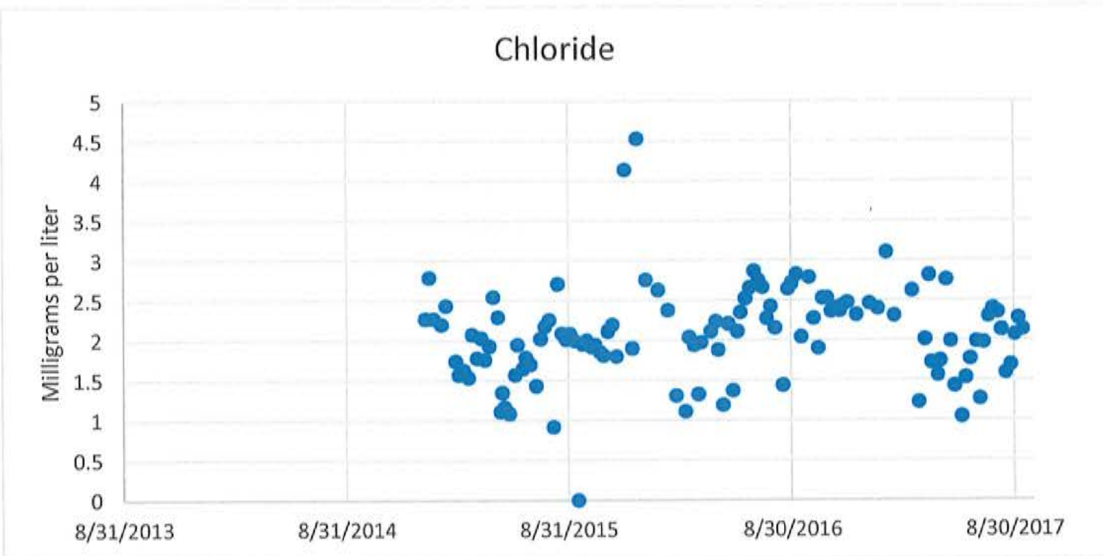


Figure 27. Chloride concentrations at spring from September 2013 through August 2017

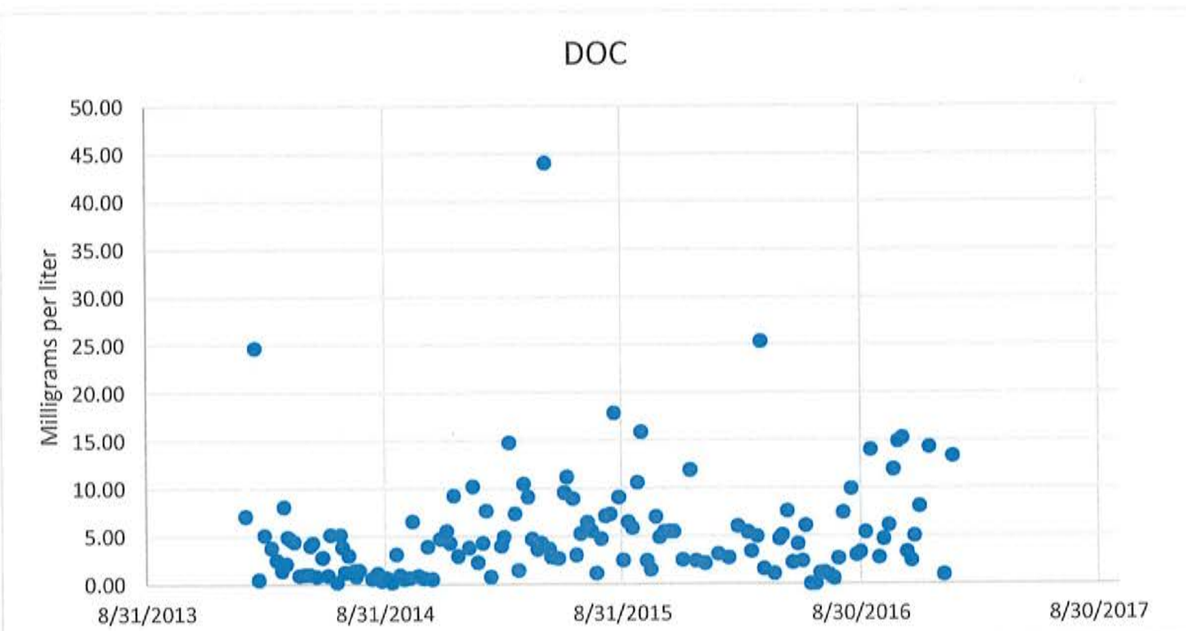


Figure 28. Dissolved organic carbon concentrations at spring from September 2013 through August 2017

11.0 Water Quality of Trench

In my opinion, water-quality from a trench downslope from the two waste holding ponds indicates that the contents from both ponds are seeping into the downslope trench.

The trench (fig. 29; description and figure from BCRET Quarterly Report, July-September 2014) is approximately 200 feet long and located approximately 150 feet downslope from the ponds and 10 feet below the base of the ponds. The trench drains to both ends with a high point in the middle. A more detailed description of the trench is given in the BCRET Quarterly Report for July-September 2014.

Parts of the following analysis of the trench data, including the approaches described below, are based on an unpublished report by hydrologist David N. Mott dated May 15, 2018 (Mott, 2018). However, to the extent that I have used his results and interpretations I concur with those results and interpretations. Table 9 is modified slightly (formatting only) from Mott's report and I independently verified the values shown. This unpublished report is included in the expert report of Thomas Aley dated May 24,2018.

Because of a lack of data previous to construction of the ponds or from a background site in similar geology three approaches and associated hypotheses were used to evaluate the data and determine if waste is leaking from one or both of the ponds into the trench.

The first approach was to compare concentrations and other values between the two ends of the trench. The hypothesis was that concentrations at the two ends should be the same—indicating that neither trench site was receiving pond waste seepage or that both were receiving the same waste.

Trench 1 and Pond 1 are to the southwest. Trench 2 and Pond 2 are to the northeast.

Figure 29. Location of waste ponds and trench collection points (from BCRET)

The water quality of the two trench sites is substantially different (table 9). This difference indicates that one or both trench sites is receiving an input other than from the background seepage from the overlying soil or regolith.

Table 9. Mean concentrations and results of two-tailed t-test comparing Trench 1 and Trench 2

[This table has been reformatted from a table in an unpublished report by Mott (2018). The highlighted mean is significantly higher than the other mean. * denotes that one value was 21.95 milligrams per liter. Mg/L is milligrams per liter, MPN is most probable number, cm is centimeter]

	Mean		Two-tailed t-test
	Trench 1	Trench 2	p-value
Dissolved phosphorus (mg/L)	0.005	0.005	Not significant
Total phosphorus (mg/L)	0.022	0.067	<0.001
Ammonia (mg/L)	0.48*	0.06	Not significant
Nitrate (mg/L)	0.542	1.585	<0.001
Total nitrogen (mg/L)	1.44	2.17	Not significant
Chloride (mg/L)	1.62	0.808	<0.001
Total suspended solids (mg/L)	8.8	13.7	Not significant
Dissolved organic carbon (mg/L)	2.03	4.87	<0.001
Total coliforms (MPN per 100 mL)	14,969	38,549	0.08
E. coli (MPN per 100 mL)	475	881	Not significant
Conductance (microsiemens per cm)	226	164	<0.001
Total dissolved solids (mg/L)	127	115	Not significant

The second approach was to assume that the trench with the highest values of waste-associated constituents must be receiving waste. Therefore, it appears that Trench 2 is receiving a source of waste that is consistently elevating the concentration of total phosphorus, nitrate, dissolved organic carbon, and total coliform above the values in Trench 1 (table 9). Although not statistically significant, Trench 2 concentrations of total nitrogen, total suspended solids, and *E. coli* are substantially higher than in Trench 1.

The third approach was to assume that if only one of the trenches is receiving pond seepage, then mean and maximum values in the other trench should always be lower than in the trench receiving a waste pond leakage input. However, Trench 1 mean values for ammonia (although not statistically significant), chloride, and conductance (also not statistically significant) are substantially higher than mean values for Trench 1. These higher means (particularly ammonia) suggest that Trench 1 also is receiving some seepage (perhaps intermittently) from the ponds.

The high mean for ammonia in Trench 1 primarily is the result of a single concentration (fig. 30). The laboratory value reported for Trench 1 on 4/24/17 was 21.95 mg/L. Leidy and Morris (1990) reported typical values for ammonia from the Boone Formation in northwestern Boone County, Arkansas during the "wet season". These values were a mean of 0.04, a minimum of 0.01, and a maximum of 0.20 mg/L. The ammonia concentration from Trench 1 was two to three orders of magnitude greater than the mean. Later samples from 4/27/17 and 5/1/17 returned ammonia concentrations of 1.04 and 0.61

mg/L, respectively, and were also substantially greater than the values from Boone County. This suggests that Trench 1 also has received waste leakage, probably from Pond 1 given the ammonia result, and high ammonia concentration (1,350 milligrams per liter) in a sample from Pond 1 collected and analyzed by the Arkansas Department of Environmental Quality (Harbor Environmental and Safety, 2016). Median ammonia concentrations from Pond 1 range (depending on sampling depth in the pond) from 1,150 to 1,437 milligrams per liter (BCRET October-December 2016 Quarterly Report).

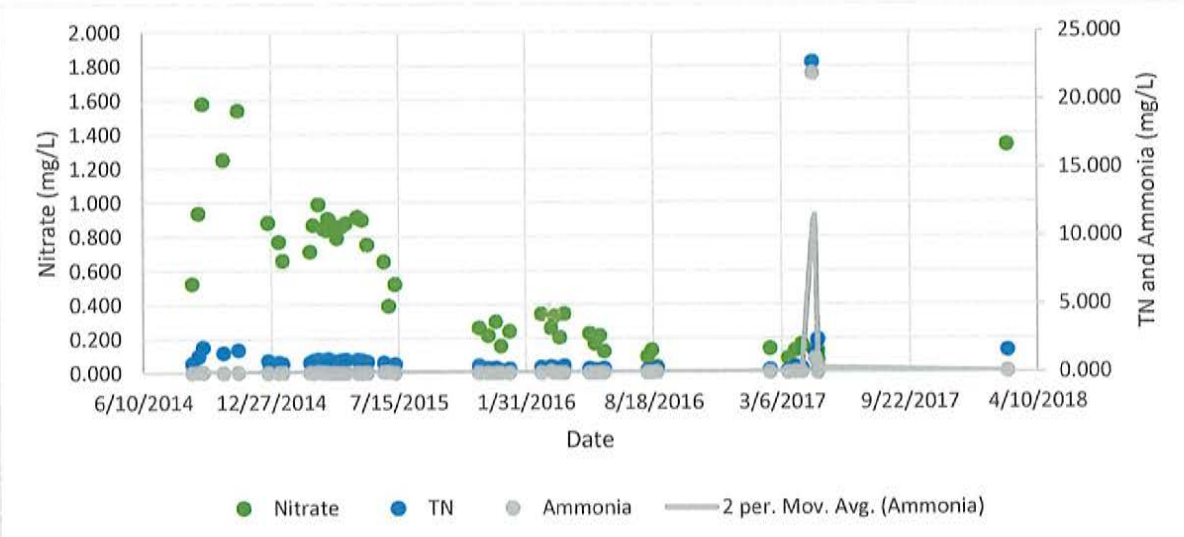


Figure 30. Nitrate, total nitrogen, and ammonia concentrations from Trench 1—including an unusually high ammonia concentration (from Mott, 2018 unpublished report)

Chloride is commonly used as a tracer to evaluate leakage from landfills, holding ponds, and contaminated areas. In the BCRET April-June 2016 Quarterly Report the use of chloride to monitor for leakage from Pond 1 and Pond 2 is suggested. I concur that this is a good approach. However, the following suggests that this might not always be a good approach: While the ammonia concentration was spiking in Trench 1, chloride concentrations declined from about 2.0 -2.5 milligrams per liter to a minimum of 0.557 milligrams per liter (fig. 31). This is unexpected given that concentrations in the ponds exceed 500 milligrams per liter (Harbor Environmental and Safety, 2016) with median concentrations ranging (depending on sampling depth in the pond) from 360 - 468 milligrams per liter (BCRET October-December 2016 Quarterly Report) and concentrations in groundwater in the Boone Formation usually exceed 1 milligram per liter (Leidy and Morris, 1990 and BCRET data). A possible geochemical explanation for the low chloride concentrations is attachment of chloride ions to clay and limestone present between the point of leakage and the point of sampling. For example, the soil testing conducted during the Harbor Drilling study showed a high correlation between clay content of the soils and chloride concentrations, indicating that these soils actively sorb chloride ions. The Harbor drilling study also detected chloride values in soils that exceeded typical values reported by Leidy and Morris (1990) in Boone County. The fluctuation of chloride values and the negative response to ammonia indicates there may be more complicated chemical interactions taking place and makes using chloride as a tracer an uncertain option until these interactions can be ruled out or understood.

Figure 31. Concurrent increase in ammonia concentration and decrease in chloride concentration in samples from Trench 1 (from Mott, 2018 unpublished report)

An additional line of evidence that the holding ponds are discharging and measurably impacting groundwater is contained within the Harbor drilling report (Harbor Environmental and Safety, 2016). The borehole drilled by Harbor had a total depth of 120.5 feet below ground surface. This depth is similar to the 138 feet noted for the static water level on the Arnold well drilling log for the house well. Because of yield issues with the borehole the Harbor authors state that the 5th and final sample "B-1GW-5 is likely mostly groundwater; as the field parameters stabilized and the borehole continued to make water." It is likely the Harbor borehole final depth had encountered the water table when sample B-1GW-5 was collected. A flaw in the assessment employed by Harbor was to compare the water sample from the borehole only to average values from wells in Boone County, Arkansas. The results should also have been compared to the nearby House Well.

The mean concentration for total phosphorus from the House Well is 0.02 mg/L and the maximum observed post BCRET retrofit and adoption of USGS standards was 0.042 mg/L. The Harbor borehole sample returned a total phosphorus concentration of 0.313 mg/L, or 14 times greater than the maximum total phosphorus concentration from the House Well, and 16 times greater than the mean. Chloride concentrations were also elevated in the Harbor borehole sample relative to the House Well. The mean chloride concentration for the spring sampled by BCRET was also substantially lower than the borehole results at 0.07 mg/L. Detection limits used by the Harbor lab for other parameters such as ammonia and total nitrogen were too high to be used in this comparison. The results indicate the location of the aquifer sampled by the Harbor borehole is receiving a source of phosphorus.

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13.0 Amendments

This report reflects information and opinions as of the date of this report. This report may be amended when additional data or information becomes available.

Signature:

James C. Petersen

October 16, 2018

14.0 Appendix A--Curriculum Vitae

I am an aquatic biologist and a water-quality hydrologist. I was a hydrologist with the U.S. Geological Survey Arkansas Water Science Center (and then the Lower Mississippi-Gulf Water Science Center) from 1979 through January 2016. During much of that time I was responsible, either individually or as part of a study team, for conducting several studies of surface-water and ground-water quality and aquatic biology in Arkansas, Missouri, and Oklahoma. Since 1992 most of these studies have been conducted in Ozark streams when I was study unit biologist and then study unit chief of the Ozark Plateaus study unit of the National Water Quality Assessment program. I have authored or co-authored more than 35 journal articles and U.S. Geological Survey reports. The topics of many of these manuscripts were water-quality statistics of Arkansas streams and the water quality and biology of surface water and groundwater of the Ozark Plateaus and Boston Mountains of Arkansas, Missouri, and Oklahoma.

I retired from the U.S. Geological Survey in January 2016 and since that time have been a freelance scientific writer/editor.

I received a Bachelor of Science degree in biology in 1975 with an emphasis in fisheries biology from the University of South Dakota. I received a Master of Science degree from Oklahoma State University in zoology in 1979 with an emphasis in water-pollution biology. During my time with the U.S. Geological Survey (USGS) I took training courses in hydrologic statistics, water-pollution biology, organic chemistry, project planning and report writing at the USGS National Training Center.

Prior Testimony: I have not previously provided deposition or trial testimony.

Publications

The following are two sets of scientific publications that I have authored/co-authored (those most pertinent to evaluation of Big Creek hydrology; other publications):

Publications most pertinent to evaluation of Big Creek hydrology:

U.S. GEOLOGICAL SURVEY SIR 2014-5009
Effects of Land Use, Stream Habitat, and Water Quality on Biological Communities of Wadeable Streams in the Illinois River Basin of Arkansas, 2011 and 2012
James C. Petersen, B.G. Justus, and Bradley J. Meredith

U.S. GEOLOGICAL SURVEY SIR 2012-5086
Seasonal Patterns in Nutrients, Carbon, and Algal Responses in Wadeable Streams within Three Geographically Distinct Areas of the United States, 2007-08
Kathy E. Lee, David L. Lorenz, James C. Petersen, and John B. Greene

A Comparison of Algal, Macroinvertebrate, and Fish Assemblage Indices for Assessing Low-Level Nutrient Enrichment in Wadeable Ozark Streams. Ecological Indicators (2010)
B.G. Justus, James C. Petersen, Suzanne R. Femmer, Jerri V.Davis, and J.E. Wallace

U.S. GEOLOGICAL SURVEY OFR 2007-1302
Methods for Monitoring Fish Communities of Buffalo National River and Ozark National Scenic Riverways in the Ozark Plateaus of Arkansas and Missouri: Version 1.0
James C. Petersen, B.G. Justus, H.R. Dodd, D.E. Bowles, L.W. Morrison, M.H. Williams, and G.A. Rowell

U.S. GEOLOGICAL SURVEY SIM 2005-2908
Fishes of Buffalo National River
James C. Petersen

U.S. GEOLOGICAL SURVEY SIR 2005-5130
The Fishes of Buffalo National River, Arkansas, 2001-2003
James C. Petersen and B.G. Justus

U.S. GEOLOGICAL SURVEY OFR 2004-1277
Stream Habitat and Water-Quality Information for Sites in the Buffalo River Basin and Nearby Basins of Arkansas, 2001-2002
James C. Petersen

U.S. GEOLOGICAL SURVEY SIR 2004-5119
Fish Communities of the Buffalo River Basin and Nearby Basins of Arkansas and their Relation to Selected Environmental Factors, 2001-2002
James C. Petersen

U.S. GEOLOGICAL SURVEY CIRCULAR 1158
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U.S. GEOLOGICAL SURVEY WRI 2002-4024
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James C. Petersen, Brian E. Haggard and W. Reed Green

U.S. GEOLOGICAL SURVEY WRI 2002-4210
Periphyton Communities in Streams of the Ozark Plateaus and Their Relations to Selected Environmental Factors
James C. Petersen, and Suzanne R. Femmer

U.S. GEOLOGICAL SURVEY FS 092-99
Quality of Ozark Streams and Ground Water, 1992-1995.
James C. Petersen, James C. Adamski, Richard W. Bell, Jerri V. Davis, Suzanne R. Femmer, David A. Freiwald and Robert L. Joseph

U.S. GEOLOGICAL SURVEY WRI 98-4155
Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Fish Communities in Streams and Their Relations to Selected Environmental Factors
James C. Petersen

U.S. GEOLOGICAL SURVEY WRI 95-4042
Water-Quality Assessment of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma-Analysis of Information on Nutrients, Suspended Sediment, and Suspended Solids, 1970-92
Jerri V. Davis, James C. Petersen, James C. Adamski, and David A. Freiwald

U.S. GEOLOGICAL SURVEY WRI 94-4022
Environmental and Hydrologic Setting of the Ozark Plateaus Study Unit, Arkansas, Kansas, Missouri, and Oklahoma
James C. Adamski, James C. Petersen, David A. Freiwald, and Jerri V. Davis

U.S. GEOLOGICAL SURVEY WRI 92-4044
Trends in stream water-quality data in Arkansas during several time periods between 1975-1989
Petersen, J. C.

U.S. GEOLOGICAL SURVEY WRI 90-4017
Trends and comparison of water quality and bottom material of northeastern Arkansas streams, 1974-85, and effects of planned diversions
Petersen, J. C.

U.S. GEOLOGICAL SURVEY WRI 88-4112
Statistical summary of selected water-quality data (water years 1975 through 1985) for Arkansas rivers and streams
Petersen, J. C.

U.S. GEOLOGICAL SURVEY OFR 84-727
Compilation of data collected and derived for water years 1980 and 1981 for the purpose of water-quality modeling of the lower Ouachita River and selected tributaries, south-central Arkansas
Petersen, J. C.; Morris, E. E.

U.S. GEOLOGICAL SURVEY WRI 83-4092
Water-quality assessment of the Illinois River basin, Arkansas
Terry, J. E.; Morris, E. E.; Petersen, James C.; Darling, M. E.

Other publications:

U.S. GEOLOGICAL SURVEY SIR 2012-5246
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New distributional records of lampreys from Arkansas. 2006. *Henry W. Robison, C. Renn Tumlinson, James C. Petersen. Journal of the Arkansas Academy of Science vol. 60, article 35.*

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James C. Petersen and B.G. Justus

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Petersen, James C.

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Petersen, James C.

U.S. GEOLOGICAL SURVEY OFR 81-806
Water-quality reconnaissance of Patton Lake, Jefferson County, Arkansas
Petersen, James C.

15.0 Appendix B--Methods Used for Analysis of Nutrient Management Watershed Concentrations and Yields

To estimate the flux (an instantaneous load, calculated as the product of the concentration of an individual sample and the 15-minute streamflow), yield (calculated as the flux divided by the drainage area), and concentrations for waters flowing from the pasture areas of the BC6 watershed and the Nutrient Management Watershed, a several step process was used to examine nitrate and dissolved phosphorus data. The process included estimation of streamflow at BC6, estimation of concentrations of nitrate and total phosphorus in water from hypothetical watersheds with 100 percent forest land use, and use of two component mixing models. The ultimate goal of this process was to estimate the yield (mass per second per square mile) and concentration of nitrate and total phosphorus from areas of pasture land use in the Nutrient Management Watershed and the BC6 watershed. The individual pasture yields from the BC6 and Nutrient Management Watershed watersheds were compared using the Wilcoxon Signed Rank Test and trends were analyzed using Spearman's rank correlation. For trend analysis the data were restricted to October 1, 2014 to September 30, 2017 to avoid seasonal bias. The trend analysis was performed on the difference ($\triangle$ yield, Nutrient Management Watershed yield minus BC6 watershed yield) between the two watersheds. Steps in the process are listed below.

1. Streamflow for BC6 was estimated using the following equation:
   Flow at BC6= (Flow at BC7 -2.4 ft^3/sec) x 0.67

   where 2.4 ft^3/sec is the approximate flow at BC7 when BC6 stops flowing
   where 0.67 is the watershed ratio for the drainage areas of BC6 and BC7

2. Two-component mixing models (Mott and Steele, 1991) were used to calculate concentrations from forest and pasture lands from the BC6 and NMW watersheds for each of the sample collections. The models were of the form:
   $Q_{DS} \times C_{DS} = (Q_f \times C_f) + (Q_p \times C_p)$, where Q is streamflow, C is concentration, DS is the BCRET site at the downstream end of the watersheds (BC6 for the BC6 watershed, BC7 for the NMW watershed), f is forest, and p is pasture.

   The equations were rewritten to solve for the unknown, C_p. C_f was estimated from a regression fit of mean concentration with percent pasture in the watershed for Buffalo National River sites on Richland Creek, Beech Creek, and the Buffalo River (near Boxley) and site BC6. For a few constituents C_f estimated using best professional judgment. The resulting regression equations were solved for a watershed with 0 percent pasture. Q_f and Q_p were calculated by multiplying the Q for BC6 or BC7 times the proportion of forest or pasture in BC6 or NMW watersheds. The rewritten equations were of the form:

$C_{p, BC6} = ((C_{BC6} * Q_{BC6}) - (C_{f, BC6} * Q_{f, BC6}))/Q_{P,BC6}$

3. Pasture concentrations (C_p) from individual samples were multiplied by the streamflow (Q_p) associated with the time and location (BC6 or BC7) of the sample and a conversion factor (28.316) resulting in an instantaneous flux (mg/sec) for each sample. Yields (mg/sec/mi^2) were calculated by dividing fluxes by the square miles associated with the area of pasture in the watershed.