Request to Deny C&H Hog Farms a Regulation 5 Permit
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Based on my following numbered objections shown below, I respectfully request that the Arkansas Department of Environmental Quality deny a Regulation 5 permit to C&H Hog Farms.

1. ***Major Objection—The Groundwater Component of the Water Budget Is Large in Karst Areas, and Groundwater Was Ignored in Assessing Contamination from C&H.*** The following documents showed none to very little discussion of groundwater flow or contaminant transport, although these are dominant in karst. Erroneous, incomplete, documents include: the Notice of Intent (Pesta, 2012); the Final Environmental Assessment (U.S. Department of Agriculture Farm Service Agency and U.S. Small Business Agency, 2015); Big Creek and the associated waste-spreading fields of C&H Farms are on the Boone Formation, which includes pure limestone and interbedded thin limestone and chert layers. The limestone has been intensively karstified (Braden and Ausbrooks, 2003: Hudson, 1998; Mott et al., 2000; Murdoch et al., 2016; Brahana et al., 2017). Being karstified means that much of the hydrologic budget of rainfall and wastes placed on the land surface moves underground as groundwater, and this part of the flow path is not easily seen. Multiple springs, wells, and contiguous surface-drainage basins are sampled using non-toxic dyes that are added to flowing groundwater. Dye receptors are placed in wells along the potential flow path, and at the discharge points in rivers and streams to assess if dye input flowed past each point. Dye tracing is essential in showing the pathways of water movement in karst (Quinlan; Aley; Ewers), and in the Big Creek basin where C&H

operates, multiple dye traces have been undertaken by the Karst Hydrogeology of the Buffalo National River (KHBNR) team of citizen scientists using scientifically accepted and approved methodologies. The results of these tests are currently being published in peer-reviewed scientific paper (U.S. Geological Survey Scientific Investigations Report) indicating that the groundwater flow moves underground to Big Creek, and underneath topographic divides into contiguous surface water drainage basins. It returns to the surface from springs, ultimately discharging into the Buffalo National River (Brahana et al., 2017a). In addition to flow path identification, dye tracing indicates that most groundwater flow rates are very rapid, about 2000 to more than 3000 feet per day. When the water has both surface and groundwater flow components, it can travel faster than 5 miles in a single day.

2. ***Major Objection—Intensive groundwater sampling from springs, wells and streams in the area is showing that water quality is degrading, with greatest impact occurring closest to the CAFO and springs draining its permitted spreading fields.*** In addition to the dye tracing, KHBNR team members collected water-quality data, which indicate groundwater quality is degrading. The KHBNR team, which has been collecting groundwater quality data since 2013, found that the groundwater quality near the C&H Hog Farms and its spreading fields shows high concentrations of the trace metals zinc-66, copper-63, and copper-65, additives to pig food, and the isotope phosphorus-31 (Brahana et al., 2017), common in pig excretia. Additional water quality data are enlightening, with *Escheria coli* (*E. coli*) concentrations in receiving streams (Big Creek and Left Fork of Big Creek), having values of these indicator bacteria that range well above 20,000 colonies per 100 milliliters, expressed as most probable number per 100 milliliters (MPN/100 ml). Dissolved oxygen (DO) concentrations during the summer of 2015 were less

than the lower limits of impaired streams (summertime values of 5.0 mg/L). *E. coli* is indicative of water contamination by warm-blooded animals, and DO concentrations are indicators of the overall ecological health of waters. Excessive algal blooms can be yet another indicator of impaired water quality. From the U.S. and around the world, CAFOs have a horrible record of contaminating environments unless they are properly sited and professional studies show that the feces and urine of the animal waste are properly contained.

3. ***Major Objection—The Final Environmental Assessment provided by the U.S. Department of Agriculture Farm Service Agency and the U.S. Small Business Agency is flawed and inaccurate.*** The Final EA continues to assert that the cherty section of the Boone Formation in the vicinity of the C&H hog factory is not karst. This claim of no Boone karst is based on "lack of identifiable surface features on topographic maps and areal photos" in the immediate area of the farm. This is a flawed interpretation based on an erroneous definition that karst is "karst topography", or that karst topography is always an essential component of karst. Karst is a hydrogeologic term, wherein groundwater plays a greater role in the hydrologic budget. The CAFO study site is formally called mantled karst, which means that many of the internally drained depressions (sinkholes) the EA sought on maps were covered with a thin, nearly-flat layer of insoluble soil and regolith, and therefore not visible using the methods employed by the Final EA. Furthermore, in the area of outcrop of the Boone Formation in northern Arkansas, karst topography is not visible at areal-photographic or map scales (1:24,000), because many of the karst features are too small to be seen on maps of this scale (figure 1), or below land surface (figures 2 and 3). However, Arkansas Geological Survey geologic mapping of the 7.5-minute Mount Judea quadrangle (Braden and Ausbrooks, 2003), was described and based on intensive field work. Description of the Boone Formation includes this statement: "Boone Formation (Lower Mississippian, Osagean and Kinderhookian) – Coarse-grained fossiliferous and fine-grained limestones interbedded with anstamosing and bedded chert. Light to medium-gray on fresh surface but usually weathers dark-gray. The chert varies in color from light-gray to dark-gray. Springs and sinkholes are abundant…" If sinkholes are present, so is karst.

A further claim that the Mt. Judea topographic map (U.S. Geological Survey, 1980) was used for identification of karst features visible on the land

surface appears to be scientifically inconsistent, inasmuch as names of streams that drain the region within 1 mile of the CAFO have names shown clearly on the map as Dry Creek, Cave Spring Branch, and Dry Branch, strongly suggesting that the area is likely underlain by karst. This was not evaluated nor pursued in any of the documentation offered, including the Notice of Intent (NOI), the draft EA, or the Final EA.

Another field-observable feature, erroneously interpreted from the 7.5-minute topographic map (U.S. Geological Survey, 1980), interprets Big Creek near C&H Hog Farms and its spreading fields as a continuously flowing stream and Dry Creek as an intermittent creek. In fact, under varying recharge and seasonal conditions, both show dry-stream reaches, zones of continuous streamflow upstream of dry reaches where streamflow has ceased (Brahana and Hollyday, 1988). Dry-stream reaches reflect underlying karst, where all streamflow is captured in an interval that flows completely underground.

The continued denial of the existence of karst in the Final EA not only fails to describe actual environmental conditions in Big Creek basin in the vicinity of the CAFO, it represents a serious flaw in the argument of a FONSI. The definition of karst in the Final EA ignores consideration of the key fact that the area is underdrained by interconnected zones of high permeability created by dissolution of the soluble bedrock. This is an essential component of the definition of karst, not the limited aspects of "karst topography" to which the Final EA erroneously and steadfastly adheres. Because the waste, the contamination, and the water have moved underground and bypassed many of the surface measuring sites that the Final EA used to establish a FONSI, this negates claims that there is no impact from C&H. The Big Creek Extension and Research Team (BCRET) funded with tax dollars by Governor Beebe at the request of the Farm Bureau in 2013 acknowledges karst in some of their ancillary documents, but their focus is not karst. The Final EA simply failed to sample the natural groundwater outlets (springs) downstream from the karst resurgences, water and waste derived initially from the hog-waste spreading fields.

Scientific data collection by the Karst Hydrogeology of the Buffalo National River (KHBNR) team included field-based sampling starting in July 2013, when fewer than 500 hogs were housed at C&H Hog Farm. The KHBNR team rigorously followed U.S. Geological Survey (USGS) and U.S. Environmental Protection Agency (EPA) protocols and procedures, conducting karst inventorying, dye-tracing studies, major constituent water-quality sampling, continuous groundwater level monitoring, trace-metal sampling, microbial sampling, and dissolved oxygen analyses with continuous-sampling probes. The Final EA

claims to adhere to the "best science", implying unbiased, fair assessment of all scientific facts that are readily available, but made no effort to pursue any data from KHBNR. KHBNR includes retired professors (Ph.D.s), professional geologists (P.G.s), previous employees of state and federal agencies (Arkansas Department of Environmental Quality [ADEQ], USGS, and National Park Service [NPS]), consultants, and graduate students. Discipline backgrounds are diverse, all are well-informed, honest, concerned citizens who pay the taxes that ultimately have provided funding for the EA, as well as for the BCRET study. The claim of "best science" is hollow unless the Final EA provides a full discussion of KHBNR data and interpretations, including the web address https://buffaloriveralliance.org under numerous headings of data, research and Dr. Van Brahana in red. This was done for BCRET webpage (page 3.8 of Section 3.2.1, Surface Water section of the Final Environmental Assessment), but not for KHBNR, the website where these important data and studies reside. The present Final EA reinforces the appearance of bias.

Field observation conclusively provides visual documentation that karst is indeed present in the immediate area of the CAFO and its spreading fields. The Final EA requires a thorough and adequate reevaluation of the karst groundwater prior to the finding of a FONSI. No groundwater nor karst studies were used nor studied, further discrediting the Final EA.

Another major flaw of the Final EA is the lack of discussion of the relation of surface and groundwater, clearly pointed out by Tom Aley (2015) and myself (Brahana, 2015) in the draft EA. Karst scientists understand that the degree of groundwater/surface water interaction in Big Creek basin is another major characteristic of karst. Stated simply, water and waste in karst lands are not confined only to surface streams, but flow underground along unseen pathways until resurgence as springs or baseflow to surface streams occur (Winter et al., 1998). Figure 7 shows the relation of precipitation measured at 10-minute intervals over the course of more than a year, as well as the timing of water level response in several key wells in the area, and the stream level in Big Creek. Cause and effect are nearly coincident. The nearly identical timing of response of wells and the stream (near-identical lag times) clearly establishes the fact the water in the Boone Formation has moved from surface to groundwater amazingly rapidly, an essential characteristic of karst.

One reason for establishing the existence of close groundwater/surface water interaction concerns the economics of widely spreading dye on the waste-spreading fields. Dye injection into a point source ("dug" wells), rather than areally broadcasting a large amount of dye on the waste-spreading fields (for which we have not been given permission by the CAFO and spreading field owners) requires much less dye be utilized in the test. Because: 1) the KHBNR

is operating on a meager budget that is based on donations of cash and *pro bono* contributions of field sampling and lab analyses; because the cost of the dye represents a large part of the KHNBR budget; because some of our fluorescent dyes photodegrade on land surface in sunlight; and because these "dug" wells offer direct access to flowing groundwater in the Boone aquifer, we can optimize our scientific study while minimizing our expenditures.

The third major flaw in the Final EA is the continued ignoring of dye-tracing studies that have been conducted and described in peer-reviewed literature (Brahana et al., 2014; Kosic et al., 2015), and the noted existence of these studies in my previous review of the preliminary EA (Brahana, 2015). One such study is shown here, with the injection occurring in a dug well surrounded by waste-spreading fields, and wide and rapid dispersal of the dye not only in Big Creek, but in contiguous drainage basins, and downgradient as far as the Buffalo National River (figure 8). It should be noted that within 24 hours of dye injection, a major storm of about 6 inches of rain fell, and this recharge facilitated the rapid groundwater level rise and mobilization of the dye.

Completely discounting the key details of the dye-tracing studies, including very rapid groundwater flow velocities and unexpected groundwater flow dispersal that the KHBNR team has established, ignores well-documented and important data that have a direct bearing on a FONSI. Dye tracing is an essential tool for studying karst hydrogeology, and the KHBNR dye studies utilize extensive experience involving project planning and objectives, challenging field conditions, thorough karst inventorying, and rigorous QA/QC (Aley, 2002). KHNBR studies were conducted to the highest of scientific standards (Brahana et al., 2014; Kosic et al., 2015). The importance of dye tracing in karst is that it documents where the water and waste flows in the subsurface (in this case, from a well immediately across the road from the pig factory, and another well surrounded by waste spreading fields near Dry Creek), how fast it flows (from about 1700 to 2500 feet per day), and the location where it reemerges at springs (in the middle of Big Creek, along upstream and downstream tributaries to spreading fields, and springs in Left Fork of Big Creek), and at 7 locations along the Buffalo National River (figure 8). None of this was mentioned in the Final EA. Especially noteworthy, dye recovery at John Eddings Cave from dye injection at BS-36 during conditions of high groundwater flow clearly indicates an hydraulic connection between CAFO waste-spreading fields and this cave. John Eddings Cave is a recognized hibernaculum for the endangered gray bat, *Myotis grisescens*. By failing to reference this most relevant information, it is my opinion that the Final EA has failed to pursue the potential for negative environmental impact to this

Dye-tracing results in Big Creek are mirrored by many other researchers

throughout the Buffalo National River, especially with reference to the hydrogeology of the Boone Formation and its karst nature (Aley and Aley, 1989; Mott, 2003; Soto, 2014; Aley, 2015; Kosic et al., 2015; Brahana et al., 2017a).

Water-quality trends of dissolved oxygen (DO) as measured continuously in Big Creek during the past few summers indicate disturbing long-term decreases below calculated EPA standards, prompting a request by the National Park Service (NPS) that Big Creek be assigned "impaired" status last summer (Usrey, 2013; Usrey, 2015). DO measurements were ignored in the Final EA, and the "impaired" status request was rejected by the Arkansas Department of Environmental Quality (ADEQ) because the NPS data-collection scheme did not originate from an approved lab. This is the first time that ADEQ rejected NPS water-quality data, an unexpected decision, especially considering the time and careful development and rigorous sampling protocols implemented, clearly written, and carefully followed by NPS and USGS scientists (Green and Usrey, 2014).

The duration and extent of the low nighttime DO concentrations the last few summers (Usrey, 2013; Usrey, 2015) reinforces the observation that the added burden of waste from 6500 pigs, creating more than 2 million gallons of feces and urine per year is producing an impact in Big Creek, and downstream in the Buffalo. Informal observation by local landowners along the creek that the algae and biomass was particularly luxuriant last summer, following about 6 months of waste spreading on nearby CAFO fields. These values alone are not necessarily proof that the hog factory is the cause of the degraded water quality, but they are remarkably consistent that this CAFO has added to the total agricultural loading from this valley, and that data exist to suggest that it is stressed.

As a comparison of water quality in Big Creek with a nearby surface stream, the Little Buffalo River, the DO concentration in the Little Buffalo 7 miles upstream from the confluence of Big Creek and the Buffalo River dropped below 6 parts per million only 1 time (less than 3 hours total for the period of measured) during the sampling interval of summer 2013. The drainage area of the Little Buffalo River has similar land use and karst geology as Big Creek; what is not similar is that the Little Buffalo River does not have a huge hog factory upstream. Waiting until these water-quality degradations to build up to greater than EPA levels before seeking remediation for Big Creek and the Buffalo National River, Arkansas' Extraordinary Water Resource, seems short-sighted and potentially risky.

4. ***Major Objection—The original notice of intent (NOI) had fraudulent signatures, inaccurate map locations, errors of scientific fact, omissions of required legal and numerous***

flaws clearly reported by an independent Civil Engineering M.S. graduate (Hovis, 2014). This report is an eye-opening account of shortcomings in the NOI by an individual who had no bias. If you would like a copy of this paper, it is available on the Buffalo River Watershed Alliance webpage, or you can request a copy from me. I encourage all politicians, all ADEQ personnel, and all interested stakeholders to read this. She documents misrepresentations of who owned land that was reported to be available for spreading feces and urine, it includes factual misrepresentations in the NOI, coupled with secretive awarding of the General Permit without the knowledge of the Director of ADEQ, and allowing only two ADEQ employees from Little Rock to perform inspections at C&H. This demand was initiated after a surprise inspection by the ADEQ employees from the Jasper, Arkansas, office, who were later forbidden to continue with any addition inspections.

5. ***Major Objection—Design of the BCRET sampling plan did not include intensive groundwater data sites, which are essential to describe the hydrology of Big Creek and contiguous basins.*** Discontinuous flow along sections of Big Creek during low flow make flow and water-quality comparisons highly questionable, owing to the fact that major aspects of the hydrology are neither monitored nor quantified. This is a common feature of surface water in karst lands. The title of the BCRET sampling, paid for by "Rainy Day Funds" by the Governor, is stated in the title of BCRET reports; it is "DEMONSTRATING AND MONITORING THE SUSTAINABLE MANAGEMENT OF NUTRIENTS ON C&H FARM IN BIG CREEK WATERSHED". Governor Beebe indicated that he was funding the project to assess if the CAFO were impacting Big Creek and the Buffalo National River, not to help the CAFO find the least-harmful impact on the environment. This overall emphasis of "Demonstrating"…overall "Sustainability" implies a strong bias

we has been consistent since the CAFO was permitted.

Historical documents, long-term studies by the U.S. Geological Survey throughout the conterminous U.S., and from numerous locations throughout the world indicate that huge concentrations of animal feces and urine will follow the laws of physics and chemistry, and contaminate downstream waters. In karst regions, this is exacerbated by the high permeability of the conduits to allow rapid flow, with little attenuation of the contaminants. Big Creek and contiguous drainage ways that flow into the Buffalo National River in Newton County, Arkansas, show degraded effects of animal production. Recent study of groundwater by the KHBNR team shows strong evidence that springs and wells closest to the waste sources are seeing the most impact. Delaying action, whether by inactivity or by requesting "needed additional years of data collection" ignores the wisdom we have gained from so many other sites. For these and numerous other reasons, I strongly urge you to DENY the permit request to C&H CAFO.

6.

Aley, Tom, 1982, Characterization of Groundwater Movement and Contamination Hazards on the Buffalo National River, Arkansas: Ozark Underground Laboratory, Protem, Missouri.

Aley, Tom, 1988, Complex radial flow of ground water in flat-lying residuum-mantled limestone in the Arkansas Ozarks; In: Environmental Problems in Karst Terranes and Their Solutions, National Water Well Association, Dublin, Ohio Proceedings, v. 2, p. 159-170.

Aley, Thomas, 1999. Inventory and delineation of karst hydrological features, Buffalo National River, Arkansas: Ozark Underground Laboratory, Protem, Missouri.

Aley, Thomas, 2015. A technical assessment of the adequacy and accuracy of the draft Environmental Assessment for C&H Hog Farms, Newton County, Arkansas: Testimony for presentation at a public hearing August 27, 2015, at Jasper, Arkansas, unpublished document submitted to U.S. Department of Agriculture Farm Service Agency and U.S. Small Business Agency, 17 p. http://buffaloriveralliance.org/Resources/Documents/Tom%20Aley%20hog%20farm%20assessment.pdf Accessed on 1/27/2016.

Aley, Tom and C. Aley, 1989. Delineation and characterization of the recharge area for Mitch Hill Spring, Buffalo National River, Arkansas: Ozark Underground Laboratory, Protem, Missouri.

Al-Qinna, Mohammed, Scott, H.D., Brye, K.R., Brahana, J.V., Sauer, T.J., and Sharpley, A.N., 2014, Coarse fragment effects on soil physical and hydraulic properties in a mantled-karst landscape in the Ozark Highlands: Soil Science, v. 179, no. 1, p. 42-50,

Big Creek Research and Extension Team (BCRET), 2014, 2015, 2016, Demonstrating and monitoring the sustainable management of nutrients on C&H Farm in Big Creek Watershed: Quarterly Reports 1 through 9 –October 2013 through December 31, 2015, variable pagination: University of Arkansas System, Division of Agriculture. http://www.bigcreekresearch.org/project_reports/ Access

ed on 1/27/2016.

BCRET Expert Panel, 2014, Unpublished memorandum of the adequacy and effectiveness of an external review of sampling methodologies on the C & H factory to Dr. Mark Cochran, Vice-President for Agriculture, University of Arkansas, Little Rock, AR; Expert Panel members included Dr. Carl Bolster, Agricultural Research Service, U.S. Department of Agriculture, Bowling Green, KY; Dr. Lee J. Florea, P.G., Department of Geological Sciences, Ball State University, Muncie, IN; Dr. Martin J. Shipitalo, Agricultural Research Service, U.S. Department of Agriculture, Ames, IA; Mr. Mark Rice, Department of Biological and Agricultural Engineering, North Carolina State University, Raleigh, NC. 20 p. .
http://buffaloriveralliance.org/Resources/Documents/BCRET%20Peer%20Review.pdf Accessed on 1/28/2016.

Braden, Angela, and Ausbrooks, Scott, 2003, Geologic map of the Mt. Judea Quadrangle, Newton County, Arkansas: Arkansas Geological Commission, scale 1:24,000.

Brahana, J.V., 1997, Rationale and methodology for approximating spring-basin boundaries in the mantled karst terrane of the Springfield Plateau, northwestern Arkansas: in Beck, B.F. and Stephenson, J. Brad, eds., Sixth Multidisciplinary Conference on Engineering Geology and Hydrogeology of Karst Terranes, A.A. Balkema, Rotterdam, p. 77-82.

Brahana, John Van, 2015, Comments of Professor John Van Brahana on draft Environmental Assessment for C& H Hog Farms 14 p. and *Curriculum Vita*, Establishing professional credentials in karst, in hydrology, in hydrogeology, in geology and related professional credentials, 35 p. http://buffaloriveralliance.org/Resources/Documents/Ex%201%20-%20FINAL%20Brahana%20statement%20with%20CV.pdf Accessed on 1/27/2916.

Brahana, Van, Bitting, Carol, Kosič Ficco, Katarina, Turk, Teresa, Murdoch, John, Thompson, Brian, and Quick, Ray, (in press) 2017a, Utilizing fluorescent dyes to identify meaningful water-quality sampling locations and enhance understanding of groundwater flow near a hog CAFO on mantled karst—Buffalo National River, southern Ozarks: *in* Kuniansky, E.L., and Spangler, L.E., eds., U.S. Geological Survey Karst Interest Group Proceedings, San

Antonio, Texas, May 15-May 17, 2017, U.S. Geological Survey Scientific Investigations Report 2017-5035, 26 p.

Brahana, V., Nix, J., Kuyper C., Turk, T., Usrey. F., Hodges, S., Bitting, C., Ficco, K., Pollock, E., Quick, R., Thompson, B., and Murdoch, J., 2017b, Geochemical processes and controls affecting water quality of the karst area of Big Creek near Mt. Judea, Arkansas: Journal of the Arkansas Academy of Science, v. 70, p. 45-58.

Brahana, Van, Nix, Joe, Bitting, Carol, Bitting, Chuck, Quick, Ray, Murdoch, John, Roland, Victor, West. Amie. Robertson, Sarah, Scarsdale, Grant, and North, Vanya, 2014, CAFOs on karst—Meaningful data collection to adequately define environmental risk, with specific application from the southern Ozarks of northern Arkansas: *in* Kuniansky, E.L., and Spangler, L.E., eds., U.S. Geological Survey Karst Interest Group Proceedings, Carlsbad, New Mexico, April 29-May 2, 2014, U.S. Geological Survey Scientific Investigations Report 2014-5035, p. 87-96.

Halihan, T., and Fields, J., 2015, Electrical resistivity surveys of applied hog manure sites, Mount Judea, AR. Final Report, Oklahoma State University, Stillwater, OK. Accessed at http://www.bigcreekresearch.org/related_material/2016_Fields%20and%20Halihan_ER%20Surveys%20of%20Applied%20Hog%20Manure%20Sites%20MTJ%20AR%2004.

Harbor Environmental and Safety, 2016a, Site investigation work plan, C and H Hog Farms, Mt. Judea, Arkansas: Little Rock, AR, accessed at - https://www.adeq.state.ar.us/water/bbri/pdfs/20160801-c-and-h-draft-site-investigation-v1.pdf

Harbor Environmental and Safety, 2016b, Final drilling study work plan, C&H Farms, Mt. Judea, Arkansas: Little Rock,

AR. Accessed at – https://www.adeq.state.ar.us/water/bbri/c-andh/pdfs/final-drilling-study-work-plan-8-26-16.pdf

Field, Malcolm, 2011, CAFOs in karst: How to investigate concentrated animal feeding operations in soluble rock terranes for environmental protection: unpublished EPA document

Fields, Jon, and Halihan, Todd, 2015, Preliminary electrical resistivity surveys of Mt. Judea alluvial sites—2nd Quarter 2015 Report (draft): unpublished report to the Big Creek Research and Extension Team, Oklahoma State University, Boone Pickens School of Geology, Stillwater, Oklahoma, 24 p. http://www.bigcreekresearch.org/OSU%20ER%20Report%202015.pdf Accessed 1/27/2016.

Green, W. Reed, and Usrey, Faron D., 2014, Guidelines and procedures for monitoring dissolved oxygen in streams within Buffalo National River, Arkansas: U.S. Geological Survey, Administrative Report, 30 p.

Hovis, Samantha, 2014, C&H hog farms: An investigation into the permitting of a concentrated animal feed operation in the Buffalo River Watershed: University of Arkansas, unpublished Civil Engineering M.S. report, 90 p.

Hudson, M.R., 1998, Geologic map of parts of the Gaither, Hasty, Harrison, Jasper, and Ponca Quadrangles, Boone and Newton Counties, Northern Arkansas: U.S. Geological Survey Open File Report 98-116, Denver, Colorado.

Kosič, Katarina, Bitting, Carol L., Brahana, John Van, and Bitting, Charles J., 2015, Proposals for integrating karst aquifer evaluation methodologies into national environmental legislations—Case study of a concentrated animal feeding operation in Big Creek Basin and Buffalo National River, Arkansas, USA: Sustainable Water Resources Management, v. 1, p.363-374. (DOI 10.1007/s40899-015-0032-5)

Murdoch, John, Bitting, Carol, Brahana, John Van, 2016,

Characterization of the karst hydrogeology of the Boone Formation in Big creek Valley near Mt. Judea, Arkansas—Documenting the close relation of groundwater and surface water: Environmental Earth Sciences, v. 75;1160, 16 p. (DOI 10.1007/s12665-016-5981-y)

Mott, David N., 2016, Permitted concentrated animal feeding operation assessment Buffalo National River: unpublished report to the National Park Service Water Resources Division, Harrison, Arkansas, 95 p.

Mott, D.N., Hudson, M.R., and Aley, T., 2000, Hydrologic investigations reveal interbasin recharge contributes significantly to detrimental nutrient loads at Buffalo National River, Arkansas: Proceedings of Arkansas Water Resources Center Annual Conference MSC–284, Fayetteville, Ark., p. 13–20.

Pesta, Nathan, for DeHaan, Grabs, and Associates, LLC, and Geoffrey Bates and Associates, Inc. (2012) NPDES Notice of Intent (NOI) Concentrated Animal Feeding Operations ARG590000, C & H Hog Farms, SSection (sic) 26, T-15-N, R-20-E, Newton County, Arkansas: Unpublished document to Arkansas Department of Environmental Quality, Mandan, North Dakota, 263 p. [https://www.adeq.state.ar.us/downloads/webdatabases/permitsonline/npdes/permitinformation/arg590001_noi_20120625.pdf] Accessed 1/28/2015.

Quinlan, J.F., 1989, Ground-water monitoring in karst terranes: Recommended protocols and implicit assumptions: U.S. Environmental Protection Agency, Research and Development, 600/X-89/050, 88 p.

Quinlan, J.F., Smart, P.L., Schindel, G.M., Alexander, Jr., E.C., Edwards, A.J.,

and Smith, A.R., 1991, Recommended administrative/regulatory definition of karst aquifer, principles of classification of carbonate aquifers, practical evaluation of vulnerability of karst aquifers, and determination of optimum sampling frequency at springs, *in* Quinlan, J.F., ed., Proceedings of the third conference on hydrogeology, ecology, monitoring, and management of ground water in karst terranes: Dublin, Ohio, National Ground Water Association, p. 573-635.

Rogers, Dr. Shane and Haines, Dr. John, 2005, Detecting and mitigating the environmental impact of fecal pathogens originating from confined animal feeding operations: Review: U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Office of Research and Development,185 p. [EPA/600/R-06/021]

Soto, Limaris, 2014, Summary of previous dye tracing reports in the area of the Buffalo National River, Arkansas: U. S. National Park System, Natural Resources Stewardship and Science, Geologic Resources Division, Cave and Karst Program, 17 p.
http://buffaloriveralliance.org/Resources/Documents/Dye%20Tracing%20Summary_Buffalo%20National%20River%2011.17.2014_LSOTO%20%281%29.pdf Accessed on 1/27/2016.

Usrey, Faron D., 2015, unpublished synthesis of dissolved oxygen within the Buffalo National River and its tributaries, continuous collection of dissolved oxygen, and appropriate sampling methodologies to accurately test and verify continuous dissolved oxygen variations showing diurnal variation during low-flow summertime conditions in tributaries of the Buffalo National River.

Usrey, Faron D., 2013, Assessment of *Escherichia coli* concentrations in the surface waters of the Buffalo National River 2009-2012: Buffalo National River Report NPS/B-0100/2013, U.S. Department of the Interior, National Park Service, Buffalo National River, Harrison, Arkansas.

U.S. Department of Agriculture Farm Service Agency and U.S. Small Business Agency, 2015, Final environmental assessment C&H Hog Farms, Newton County, Arkansas: Final Environmental Assessment prepared by 39 p.

Sincerely yours,

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