NC Department of Environment and Natural Resources
Division of Water Resources
Water Planning Section
Modeling and Assessment Branch

MEMORANDUM

To:	Kathy Stecker, Modeling and Assessment Branch Supervisor
From:	Narayan Rajbhandari, Senior Environmental Specialist
CC:	Dianne Reid, Jeff Manning, Ian McMillian, Cam McNutt, Nora Deamer, Belinda Henson, and Stratford Kay
Date:	January 7, 2014
Subject:	Assessment of Natural Condition for pH in Colly Creek, Cape Fear River Basin, NC

Summary

The North Carolina classified swamp stream, Colly Creek (AU# 18-68-17), in the Lower Cape Fear Basin exhibits pH values lower than the North Carolina water quality standard 4.3. There is no noticeable anthropogenic impact in the creek. There is also no close correlation between acid rain and field pH at a Coalition monitoring station (Q8981000). Highly acidic characteristics of soils in the entire watershed show an evidence of contributing low pH to the creek. Based on the information, the water quality standard for pH for Colly Creek has not been violated. A Total Maximum Daily Load (TMDL) is not required for pH for the creek.

Introduction

In the Lower Cape Fear River Basin, Colly Creek has been listed as impaired since 2010 on the North Carolina 303(d) List due to exceedance of the State's minimum quality standard of 4.3 for pH in swamp waters. As reported in the list, the impaired segment is located from the source to the Black River (Figure 1). The assessment unit number for the impaired section of the creek is 18-68-17. The total hydrologic length of the impaired section is 34.9 miles and is designated as Class C;Sw. The Department of Environment and Natural Resources (DENR) defines Class C as waters protected for secondary recreation, fishing, wildlife, fish, and aquatic life propagation and survival, agriculture and other uses suitable for Class C. The department defines class Sw as supplemental classification intended to recognize those waters which are topographically located so as to generally have low velocities and other natural characteristics which are different from adjacent streams draining land with steeper topography. This report evaluates the pH impairment by determining if natural conditions are the cause of the apparent impairment, thus obviating the need for a TMDL.

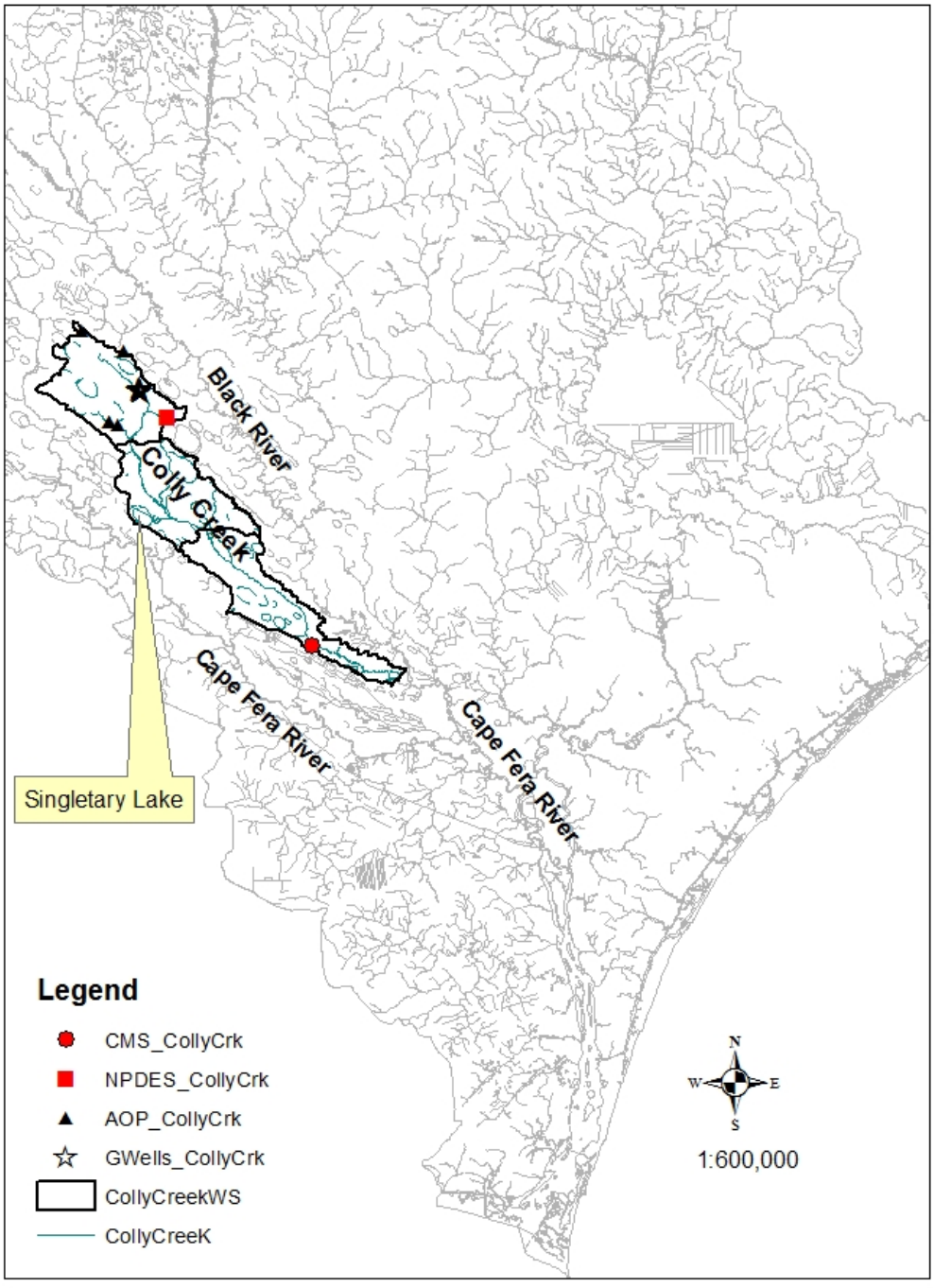

Figure 1. Colly Creek Watershed in the Lower Cape Fear River Basin

Water Quality Standard

According to the North Carolina (NC) Water Quality Standards for Class C waters (15A NCAC 02B.0211), pH shall be normal for the waters in the area, which generally shall range between 6.0 and 9.0 except that swamp waters may have a pH as low as 4.3, if it is the result of natural conditions. When greater than 10% of water samples are below the standard, the corresponding water body is assessed as impaired for aquatic life.

Natural Condition Assessment

The water quality standard, as defined above, will be more complex when elements in a watershed naturally yield low pH. Therefore, the following seven steps are selected to identify natural conditions that result in low pH levels and to determine the likelihood of anthropogenic impacts that will exacerbate the natural condition in Colly Creek:

1. Assessment of Colly Creek watershed with regards to soil classification and land uses.
2. Analysis of groundwater condition.
3. Impact from animal operation.
4. Impact from acid rain.
5. Impact from point sources.
6. Examination of seasonal and long term development.
7. Field observation.

General Description of Watershed

Colly Creek originates in Bladen County as a tributary to the Black River in the Lower Cape Fear River (LCFR) Basin (Figure 1). The watershed has an area of approximately 121.40 square miles and is predominately comprised of Woody Wetland (47%), Forested Land (25%), Shrub Land (10%), and Crop land (10%) (Table1).

There is a Coalition monitoring station (CMS) (B9891000) at NC53, where the Center of Marine Science (CMS) at the University of North Carolina at Wilmington (UNCW) collects water samples every month under the Lower Cape Fear River program to measure physical and chemical constituents in the creek (Figure 1). Additionally, the DENR Watershed Assessment Team (WAT) has collected water samples at different locations under a special study program in the creek. This study utilizes pH and nutrients measured by the CMS and the WAT.

Land Uses and Soil Type

The Colly Creek watershed is entirely composed of acidic soils (Table 1). The upper part of the watershed runs through Eolian Sands and Carolina Bays, and the lower part runs through Cape Fear River Flood Plain geographic surfaces. Forty six percent of the soils in the watershed are extremely acidic (pH is below 4.5) and 44 % are extremely to strongly acidic (pH is between below 4.5 to 5.5). Most of these acidic soils are Lynn Heaven, Pamlico and Leon types. The soils are nearly level and poorly drained and are sandy throughout surface and subsurface layers underlain by sandy material (USDA 1990).

Approximately 48% of the acidic soils are covered by woody wetlands and 25% by evergreen forest. These lands are predominantly covered by acid loving species like pine, maple and oak species. Loblolly pine (*Pinus taeda*) and Longleaf pine (*Pinus palustris*) are widely distributed throughout the watershed (Figure 3). Because pine needles have a pH ranging from 3.2 and 3.8 (http://wood.uwex.edu/2010/11/18/pine-needles-cause/), it appears that the dropped pine needles are naturally contributing to the low pH in the creek. On average, pH remained around 3.9 throughout the year with a range from 2 to 6 at the CMS station B8981000 (Table 2), suggesting no seasonal influence due to anthropogenic activities in the watershed. Approximately 86% of the samples collected were below the NC standard for swamp water.

Table 1. Land use and soil type distribution in Colly Creek watershed.

Land Types	**E (sq mi)**	**ES (sq mi)**	**EM (sq mi)**	**ESL (sq mi)**	**VS (sq mi)**	**VSM (sq mi)**	**VSS (sq mi)**	**VSN (sq mi)**	**SM (sq mi)**	**SN (sq mi)**	**NA (sq mi)**	**Sum (sq mi)**	**%**
Barren Land	0.00	0.03	0.00	0.07	0.00	0.13	0.00	0.00	0.00	0.00	0.00	0.23	0.19
Cultivated Crops	3.51	3.81	0.05	0.05	1.46	2.46	0.29	0.23	0.22	0.00	0.02	12.11	9.97
Deciduous Forest	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emergent Herbaceous Wetland	0.80	0.21	0.00	0.01	0.14	0.04	0.00	0.00	0.03	0.04	0.04	1.30	1.07
Evergreen Forest	3.20	17.46	0.30	0.43	1.14	7.31	0.46	0.08	0.15	0.01	0.05	30.59	25.2
Grassland/Herbaceous	0.26	1.35	0.00	0.14	0.24	1.51	0.04	0.02	0.03	0.01	0.00	3.59	2.96
High Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Low Intensity	0.01	0.11	0.00	0.01	0.01	0.07	0.00	0.05	0.00	0.00	0.00	0.26	0.21
Medium Intensity	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01
Mixed Forest	0.03	0.10	0.00	0.00	0.05	0.05	0.01	0.00	0.01	0.00	0.00	0.25	0.21
Open Space	0.09	0.52	0.01	0.02	0.23	0.58	0.04	0.01	0.06	0.00	0.01	1.58	1.30
Open Water	0.21	0.02	0.00	0.00	0.03	0.02	0.00	0.00	0.00	0.03	0.93	1.24	1.02
Scrub/Shrub	0.91	5.02	0.04	0.43	1.00	4.71	0.17	0.13	0.12	0.00	0.03	12.57	10.3
Woody Wetlands	36.97	15.09	0.25	0.03	1.93	1.53	0.27	0.05	1.03	0.49	0.04	57.68	47.5
Sum	45.98	43.71	0.65	1.19	6.23	18.40	1.28	0.58	1.66	0.58	1.13	121.4	100.
%	37.88	36.01	0.53	0.98	5.13	15.16	1.06	0.48	1.36	0.48	0.93	100.0	

E = Extremely Acidic; ES = Extremely to Strongly Acidic; EM = Extremely to Medium Acidic; ESL = Extremely to Slightly Acidic; VS = Very Strongly Acidic; VSM = Very Strongly to Medium Acidic
VSS = Very Strongly to Strongly Acidic; VSN = Very Strongly to Neutral Acidic; SM= Strongly to Medium Acidic; SN = Strongly to Neutral Acidic; NA = Not Available in Soil Survey.

Agriculture practices do not seem to be significantly impacting low pH in Colly Creek. Agriculture lands cover only 10% of the watershed and are predominantly used to grow blueberries (Figure 2). Because blueberries require lower pH soil beds, farmers are principally utilizing the natural environment of the watershed. As per email correspondence with David Hardy (Section Chief- Soil Testing, Agronomic Division, NC DA&CS) on 7/22/2013, farmers do not apply any fertilizers or inputs to further lower the soil pH.

Normally, farmers apply low rates of N fertilizer to blueberries for bush growth and fruit production in the Colly Creek watershed. The typical N application rate for blueberries per growing season is a total of only about 30-32 lb N per acre per year. Typically, about 7 lb N per acre from a fertilizer such as 14-28-14 is applied in April followed by another 11 lb N per acre in mid-May. The fertilizer applications do not seem to be increasing N level in the creek. Total nitrogen (TN) concentration persisted around 1mg/L throughout the months from 1996 to 2012 in the creek (Table 3), suggesting no seasonal influence due to N application in the watershed.

Table 2. Descriptive statistics of pH in Colly Creek (class C, Sw), from WWTP, and from air deposition in the Colly Creek watershed for 1996 through 2012.

Months	Colly Creek (B8981000)	WWTP (NC0023353)	Air Deposition (NC35)
1	3.721	6.56	5.200
2	3.681	6.60	5.263
3	3.806	6.52	5.217
4	3.873	6.63	3.727
5	3.906	6.74	5.345
6	3.993	6.75	5.383
7	4.286	6.92	4.982
8	4.107	6.72	4.744
9	3.750	6.50	5.376
10	3.654	6.39	5.551
11	3.947	6.52	4.954
12	3.793	6.56	5.216
Statistics			
Mean	3.89	6.62	5.19
Std Dev	0.58	0.40	0.68
Median	3.90	6.60	5.06
Max	6.60	7.40	6.82
Min	2.00	5.90	3.90
Total Observation	177	204.00	131
pH Exceeding	86%	0%	NA

Note: The NC Water Quality Standard for pH for Class C, Sw water is ≥ 4.3

Beside blueberries, farmers also grow corn, soybeans, and sweet potatoes, mainly in the upper portion of the Colly Creek watershed. Farming does not seem to have a significant effect in reducing pH level in the creek, as there have been no seasonal changes in pH (Table 2). Furthermore, average nutrient concentrations remained nearby 1.0 mg/L for total nitrogen (TN) and less than 0.1 mg/L for total phosphorus (TP) (Table 3). These averaged nutrient concentrations are near or below the USGS national background averages for natural stream (USGS, 1999). Therefore, the data do not provide any evidence that pH in the creek has been decreased by agricultural activities in the watershed.

Table 3. Averaged concentrations of nutrients at the Coalition Station, B8981000, in Colly Creek (1996-2012).

Months	NH4-N (mg/L)	NOx-N (mg/L)	TKN-N (mg/L)	OrgN (mg/L)	TN (mg/L)	TP (mg/L)
1	0.024	0.112	0.973	0.949	1.084	0.024
2	0.038	0.015	1.103	1.065	1.118	0.033
3	0.040	0.078	0.989	0.948	1.067	0.029
4	0.049	0.040	0.929	0.881	0.970	0.039
5	0.076	0.101	0.783	0.707	0.884	0.072
6	0.169	0.009	0.982	0.813	0.991	0.065
7	0.255	0.015	0.978	0.723	0.993	0.081
8	0.159	0.014	1.146	0.987	1.161	0.071
9	0.092	0.055	1.171	1.079	1.226	0.055
10	0.058	0.017	1.096	1.039	1.114	0.055
11	0.037	0.081	1.281	1.244	1.362	0.030
12	0.038	0.043	1.337	1.300	1.380	0.030
Statistics						
Mean	0.09	0.05	1.06	0.98	1.11	0.05
Std Dev	0.16	0.14	0.49	0.46	0.51	0.06
Median	0.05	0.01	0.98	0.90	1.00	0.03
Max	1.60	0.91	3.60	3.24	3.69	0.40
Min	0.01	0.01	0.20	0.11	0.21	0.01
Total Observation	180	180	180	180	180	184

Groundwater

According to Baker et al., 2013, pH ranges from less than 4.5 (extremely acidic) to less than 5.0 (very strongly acidic) in the groundwater wells installed near the headwater of Colly Creek (Figure1 and Table 4). It appears that the low pH in groundwater was affected by the surrounding acidic soils. There are three types of soils in the study area: Kalmia Loamy Fine Sand (pH = 4.5 to 6.0), Leon Sand (pH ≤ 4.5 to 5.5), and Ocilla Loamy Fine Sand (pH = 4.5 to 5.5). As water percolates through these soils, it interacts with the soils and then either discharges to the creek or infiltrates down to groundwater. This natural phenomenon further validates that the low pH in Colly Creek is due to the acidic characteristics of the soils in the watershed.

Animal Operation (AOP)

There are five hog farms; they are Cypress Creek Nursery Farm (AOP ID 408), Melvin Nursery #3 (AOP ID 375), Wayne & Susan Smith Farm (AOP ID 309), J.J. McCree Farm (AOP ID 265), and 3M & T Inc (AOP ID 269). According to the NC DENR's swine waste management system general permit number AWG 100000 (http://portal.ncdenr.org/c/document_library/get_file?uuid=3e065d07-8269-46a9-858d-d425fb3d3327&groupId=38364), all hog farms are required to maintain soil pH in all land application

fields in the optimum range for crop production. Accordingly, hog farmers in the watershed usually apply lime on their fields in order to maintain soil pH level equal to or greater than 6.0. Consequently, the hog farm lands should not be contributing low pH to the creek; rather they are helping to protect the creek from further lowering the pH level.

Table 4. Nutrients and pH concentrations in ground water near headwaters of Colly Creek.

Date	pH	Ammonia mg/L	Nitrate & Nitrite mg/L	Total Kjeldahl Nitrogen mg/L	Organic Nitrogen mg/L	Total Nitrogen mg/L	Phosphorus mg/L
5/11/2010	4.63	0.02	0.02	0.20	0.18	0.22	0.02
5/11/2010	4.90	0.02	0.02	0.20	0.18	0.22	0.02
5/11/2010	4.91	0.02	0.02	0.20	0.18	0.22	0.05
5/11/2010	4.60	0.02	0.04	0.20	0.18	0.24	0.02
5/11/2010	4.51	0.02	0.02	0.20	0.18	0.22	0.02
8/25/2010	4.67	0.02	0.02	0.20	0.18	0.22	0.02
8/25/2010	4.63	0.02	0.02	0.20	0.18	0.22	0.02
8/25/2010	4.74	0.02	0.03	0.20	0.18	0.23	0.11
8/25/2010	4.68	0.02	0.05	0.20	0.18	0.25	0.02
8/25/2010	4.71	0.02	0.14	0.32	0.30	0.46	0.02
11/3/2010	4.67	0.02	0.02	0.20	0.18	0.22	0.02
11/3/2010	4.40	0.02	0.02	0.20	0.18	0.22	0.02
11/3/2010	4.58	0.03	0.02	0.20	0.17	0.22	0.03
2/9/2011	4.34	0.02	0.02	0.20	0.18	0.22	0.02
2/9/2011	4.22	0.02	0.02	0.20	0.18	0.22	0.02
2/9/2011	4.83	0.02	0.06	0.20	0.18	0.26	0.02
Statistics							
Mean	4.63	0.02	0.03	0.21	0.19	0.24	0.03
Std Dev	0.19	0.00	0.03	0.03	0.03	0.06	0.02
Median	4.65	0.02	0.02	0.20	0.18	0.22	0.02
Max	4.91	0.03	0.14	0.32	0.30	0.46	0.11
Min	4.22	0.02	0.02	0.20	0.17	0.22	0.02
Total Observation	16	16	16	16	16	16	16

Point Sources

The White Lake Wastewater Treatment Plant (NC 0023353) is the only wastewater treatment plant discharging water directly to Colly Creek (Figure 1). It does not appear that the facility is violating its pH limit. Since 1996, the facility seems to be discharging pH at a rate of 6.6 on average (Table 2).

Acid Deposition

To understand acid deposition from rainfall in Colly Creek, the pH data are obtained from the nearby National Atmospheric Deposition Program/NTN station in Sampson County, NC (Station NC35) (http://nadp.sws.uiuc.edu). Weekly rainfall pH during the period from 1996 to 2012 averaged 5.19, with a minimum of 3.90 and maximum of 6.82 (Table 2). According to an EPA website, (http://www.epa.gov/airmarkets/acidrain/index.html) the natural pH of rain is approximately 5.5, which is close to the pH of rainfall that the creek receives every month on average. Furthermore, the relationship between acid deposition and the DWQ ambient water quality monitoring field pH data was estimated to very weak ($r = 0.17$). Therefore, it seems that acid rain is unlikely to reduce pH value further in the creek.

Long Term and Seasonal Development

Colly Creek has been reported as impaired for low pH since the 2010 NC 303(d) list. However, low pH has been documented in the creek for more than three decades. In the water samples collected in 1955 at Singletary Lake (Figure 1) that drains to the creek, one out of three samples (33%) collected had pH less than 4.3 (State Stream Sanitation Committee, 1957). For this study, the low pH values were evaluated from 1996 to 2012 and were found to have persistently low pH values throughout the time period (Table 5). Additionally, there was no indication of seasonal variation in pH in the creek as each month pH values remained below 4.3 on average (Table 2). These results suggest that the impact of anthropogenic activities on pH in the creek is negligible.

Field Observation

The DENR WAT collected water samples for a special study during April, May, and June of 2013 in different locations of Colly Creek. The study showed that the pH was lower (< 4.3) all over the creek (Table 6). Also, concentrations of TN and TP at the locations were near or slightly above national background levels for natural stream (USGS, 1999). The available data do not suggest that the pH in the creek is being influenced significantly by anthropogenic activities in the watershed.

As a follow up to this study, the DENR staff revisited the watershed on July 8, 2013 to understand the physical condition of the Colly Creek watershed. They observed that the watershed was extensively dominated by acidic sandy soils and pine forests (Figures 3). The canopy was fully covered with maple, cyprus, and oak trees (Figure 4). Extensive accumulation of leaves and twigs were not observed due to moderately high flow following a couple of rainfall events during the previous few days. However, water in the creek looked highly stained, indicating swamp water.

Table 5. Yearly percent exceeding the NC Water Quality Standard for pH at the ambient station, B8981000, in Colly Creek.

Year	Number of Observations	Total Sampled Exceeded	% Exceeded
1996	5	3	60.00
1997	9	4	44.44
1998	12	12	100.00
1999	12	11	91.67
2000	12	11	91.67
2001	12	11	91.67
2002	12	9	75.00
2003	12	11	91.67
2004	12	11	91.67
2005	12	12	100.00
2006	12	12	100.00
2007	10	5	50.00
2008	11	5	45.45
2009	11	6	54.55
2010	12	7	58.33
2011	9	8	88.89
2012	8	8	100.00

Note: The NC Water Quality Standard for pH for Class C, Sw water is ≥ 4.3

Table 6. Nutrient and pH concentrations at different locations in Colly Creek as per special study conducted by the DENR under watershed assessment program.

Site	Date	pH	D.O.	BOD	TN	TP	Comments
COL-1524	4/16/2013	2.94	5.04	2.00	1.12	0.02	Most upstream road crossing
COL-1521	4/16/2013	3.06	4.27	.		.	
COL-701	4/16/2013	3.07	4.85	.		.	
COL-41	4/16/2013	3.42	0.30	2.00	0.98	0.21	Upstream of WWTP
COL-1532	4/16/2013	3.27	1.90	2.00	1.02	0.02	Below WWTP
COL-53	4/16/2013	3.31	5.40	.		.	Coalition sampling station
COL-1524	5/22/2013	3.04	3.31	2.10	1.22	0.02	Most upstream road crossing
COL-1521	5/22/2013	3.05	3.39	.		.	
COL-701	5/22/2013	3.10	1.45	.		.	
COL-41	5/22/2013	3.33	0.31	3.30	1.82	0.28	Upstream of WWTP
COL-1532	5/22/2013	3.32	0.96	3.50		0.06	Below WWTP
COL-53	5/22/2013	3.43	5.42	.		.	Coalition sampling station

Figure 2. Blueberry farm in the Colly Creek watershed.

Figure 3. Pine forests on acidic sandy soil in the Colly Creek Watershed.

Figure 4. Colly Creek at HWY 11 with high flow on July 8, 2013.

Summary and Conclusion

- The entire Colly Creek watershed comprises acidic soils. Approximately 47.51% of the acidic soils are covered by woody wetlands and 25.20% by evergreen forest, and the majority of them are pine forests. It is recognized that pine needles are naturally maintaining the acidic level in the lands as well as discharging low pH water to the creek during rainfall events. Furthermore, infiltrated water through the acidic soils has seen to be maintaining low pH in groundwater.
- Agricultural lands cover only 10% of the watershed and are predominantly used to grow blueberries. As blueberries require a lower pH soil bed, farmers are utilizing the advantage of the acidic soils in the watershed and are not applying any fertilizers or inputs to further lower the soil pH.
- Hog farms are not seen to be contributing organic nutrients to Colly Creek as nutrient concentrations were very low near or slightly above national background levels.
- There is an active permitted NPDES discharger in Colly Creek Watershed. The facility does not seem to be violating its pH limit.
- There is no significant correlation between acid rain and field pH at the Coalition monitoring station.
- Historic data indicate that the pH in Colly Creek has been low since at least 1955.

Based on the above information, there is no evidence that Colly Creek is impaired for pH as the result of anthropogenic activities. The low pH values observed in the creek are due to natural conditions, resulting from naturally acidic soils in the watershed. For the next 305(b)/303(d) assessment, Colly Creek should be assessed as Category 1: natural conditions, no TMDL needed.

Acknowledgements

I would like express my sincere thanks to the following staff for their help and cooperation to provide information, data, and take a tour with me to the Colly Creek watershed:

- Belinda Henson, Hughie White, and Trent Allen - Fayetteville Regional Office, NC DENR.
- Dr. David Hardy and Rick Morris - Agronomic Division, NC DA&CS.
- Dr. Stratford Key – Watershed Assessment Team, NC DENR.
- Dr. JR Joshi – Animal Feeding Operation, NC DENR
- Connie Brower – Classification and Standards, NC DENR

References

Baker, V, A. Keyworth, D. Tufford, R. Vander Vorste, R. Bolich, C. Williams, W. Hankinson, R. Milosh, R. Savage, and A. Mueller. February 2013. *Hydrologic Connectivity, Water Quality Function, and Bacteria of Coastal Plain Geographically Isolated Wetlands. Final Report. EPA Grant CD 95415809*. North Carolina Department of Environment and Natural Resources (NC DENR), North Carolina Division of Water Quality (NC DWQ). Raleigh, NC.

North Carolina Department of Environment and Natural Resources (NC DENR). May 2007. Surface Waters and Wetlands Standards. *NC Administrative Code 15A NCAC 02B.0100, .0200 & 0.300.* 1617 Mail Service Center, Raleigh, NC – 27699-1617.

North Carolina Department of Environment and Natural Resources (NC DENR). *Swine Waste Management System General Permit*. http://portal.ncdenr.org/c/document_library/get_file?uuid=3e065d07-8269-46a9-858d-d425fb3d3327&groupId=38364.

State Stream Sanitation Committee, NC State Board of Health, Division of Water Pollution Control. 1957. *Cape Fear River Basin, Pollution Survey Report No. 6.* Raleigh, North Carolina.

United States Department of Agriculture (USDA). 1990. *Soil Survey of Bladen County, North Carolina*. Soil Conservation Service.

USGS (US Geological Survey). 1999. The Quality of Our Nation's Waters: Nutrients and Pesticides. *U.S. Geological Survey Circular 1225.*

University of Wisconsin. *Pine needle cause acid soil – fact or fiction*. http://wood.uwex.edu/2010/11/18/pine-needles-cause