FECAL COLIFORM BACTERIA TMDL IMPLEMENTATION ON CANE CREEK AND LITTLE CANE CREEK IN OCONEE COUNTY, SOUTH CAROLINA

George M. Huddleston III, Morris B. Warner, Louwanda W. Jolley, Nicole L. Fahrenfeld, Alan W. Elzerman, Marirosa Molina, Yong J. Lee, Robert R. Swank, Jr.

AUTHORS: George M. Huddleston III, Project Scientist, ENTRIX, Inc., 102 East Main St., Pendleton, SC 29670; Morris B. Warner, County Extension Agent, Clemson University Cooperative Extension Service, P.O Box 400, Walhalla, SC 29691; Louwanda W. Jolley, Research Specialist/Laboratory Director, Clemson University Department of Forestry and Natural Resources, 232 Lehotsky Hall, Clemson, SC 29634; Nicole L. Fahrenfeld, Graduate Research Assistant, Clemson University Department of Environmental Engineering & Earth Sciences, 342 Computer Ct., Anderson, SC 29625; Alan W. Elzerman, Professor, Clemson University Department of Environmental Engineering & Earth Sciences, 342 Computer Ct., Anderson, SC 29625; Marirosa Molina, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, GA 30605; Yong J. Lee, U.S. Environmental Protection Agency, National Exposure Research Laboratory, Athens, GA 30605; Robert R. Swank, Jr., Project Manager, Friends of Lake Keowee Society, 4065 Keowee School Rd., Seneca, SC 29672
REFERENCE: *Proceedings of the 2008 South Carolina Water Resources Conference,* held October 14-15, 2008, at the Charleston Area Event Center.

Abstract. Cane and Little Cane Creeks in Oconee County, South Carolina have been included on the state's Clean Water Act 303(d) list of impaired water bodies for violation of the fecal coliform (FC) bacteria standard since 1998. Total Maximum Daily Loads (TMDLs) for FC bacteria have been developed for both streams by the South Carolina Department of Health and Environmental Control (SCDHEC). These TMDLs call for load reductions through implementation of agricultural best management practices (BMPs), failed rural septic system rehabilitation/replacement, stormwater management and educational outreach. The objective of this project was to restore both Cane Creeks to compliance with South Carolina's FC water quality standard by: 1) implementing source controls for livestock producers and agricultural operations utilizing animal waste land application; 2) repair/replacement of failed septic systems; and 3) educational outreach and implementation of stormwater management measures. The TMDL calls for 70% reduction in the total FC load to these creeks. Preliminary surface water sampling and FC analyses were completed in the summer 2006, and strategic sampling was conducted in 2007. In June 2008, stream segments with elevated FC contamination were re-sampled and analyses to determine fecal sources were initiated. These analyses included carbon source utilization, sterol and fluorinated whitening agent (FWA) analysis, and DNA-based techniques. Recent sampling indicates that Cane Creek is in compliance for FC, although Little Cane Creek remains just out of compliance, with cattle and humans being the predominant sources of FC contamination. To date, 15 septic systems have been repaired or replaced, and an additional five approved for cost-share assistance. Application of two agricultural BMPs has been contracted, and others are being negotiated. In addition, problems discovered with the City of Walhalla sewer system have since been corrected or are being repaired.

INTRODUCTION

Both Cane and Little Cane Creeks in Oconee County, South Carolina have been included on the state's Clean Water Act 303(d) list of Impaired Waterbodies for violation of the fecal coliform (FC) bacteria water quality standard since 1998. Total Maximum Daily Loads (TMDLs) for FC bacteria have been developed for both streams (U.S. EPA, 2005). The TMDL calls for 70% reduction in the total FC load to the streams by implementation of agricultural best management practices (BMPs), failed rural septic system rehabilitation/replacement, stormwater management and educational outreach. Cost-share funding was available to property owners that implemented recommended source control measures. The objective of this project was to restore both creeks to compliance with South Carolina's FC water quality standard of 200 cfu/100 mL (geometric mean of five consecutive samples within a 30-day period with < 10% of samples >400 cfu/100 mL).

BACKGROUND AND RELATED WORK

The Cane Creek and Little Cane Creek watersheds are in Oconee County, in the foothills of the Blue Ridge Mountains of northwestern South Carolina [Figure 1] (U.S. EPA, 2005). Most of the towns of Walhalla and West Union are in the Cane Creek watershed that comprises 15.3 square miles. The Little Cane Creek watershed is more rural than that of Cane Creek, and comprises 13.9

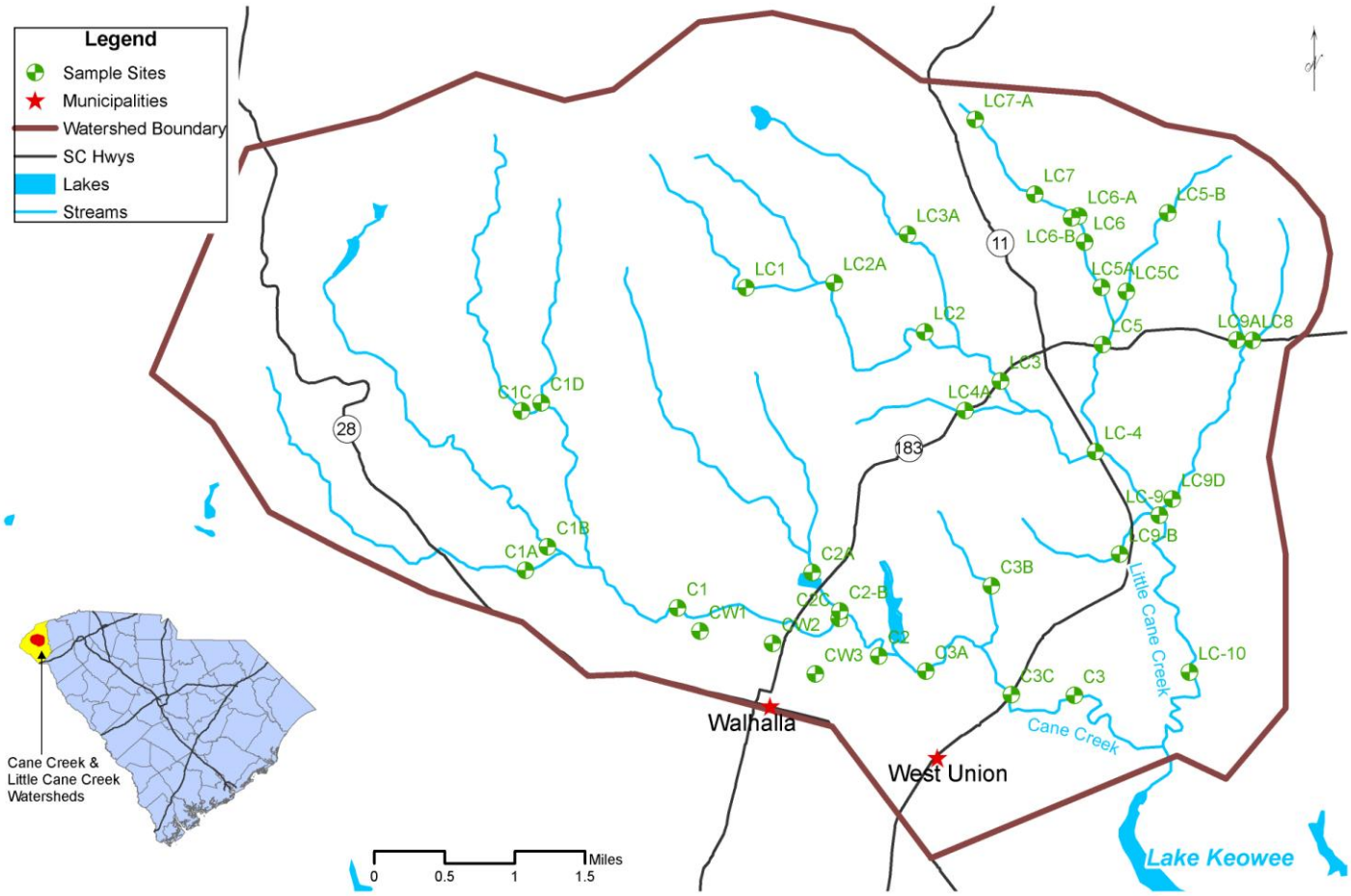

Figure 1. Cane Creek and Little Cane Creek Watershed, Oconee County, South Carolina.

square miles (U.S. EPA, 2005). Cane Creek watershed is 76% forested, 11% urban, and 11% pasture and cropland; Little Cane Creek watershed is 90% forested and approximately 9% pasture and cropland (Clemson Cooperative Extension Service, personal communication).

This work is being conducted by the Friends of Lake Keowee Society (FOLKS) in partnership with Clemson University, with partial funding from an EPA/SCDHEC CWA Section 319 grant (2/1/06-1/31/09). FOLKS began monitoring these streams under a previous EPA/SCDHEC grant for FC contamination in 2000. Using those data, along with field reconnaissance plus analysis of 2005 aerial photographs depicting land use activities, monthly SCDHEC data (2004-2006) from two monitoring stations (one on each stream), and our preliminary data from 2006, potential problem areas within the watersheds were identified. This provided the basis for conducting synoptic sampling of both creeks and their tributaries to isolate segments for source identification and implementation of mitigation activities.

EXPERIMENTAL DESIGN

Having identified the likely problem areas, thirty-five sites were sampled between three and eight times from August 15 to October 1, 2007 for FC analysis. Problem stream segments were confirmed and mitigation practices (BMPs, septic repairs, etc.) were initiated where property owners were willing to undertake cost-share improvements. In June 2008, problem sites were re-sampled for the purpose of applying preliminary FC source identification analyses and to assess overall efficacy of previously installed FC source controls.

METHODS

Surface water grab samples were collected at base flow not less than 48 hours after a rainfall event exceeding 0.25 inches using sterile 250 or 500-mL Nalgene polypropylene bottles. Samples were collected approximately three feet from the bank and approximately six inches below the water surface, or at

the surface if the stream was less than one foot deep. Care was taken not to disturb bottom sediment. Each sample was labeled with time, date, location, and initialed by the sampler. All sampling locations were marked using a hand-held global positioning system. Samples were placed on ice in coolers at 1 to 4 °C and transported to the participating laboratories within four hours of collection. Chain of custody forms accompanied all samples. Quality assurance/quality control included split samples analyzed at independent laboratories, trip blank samples, and temperature blanks.

Fecal coliform analyses were conducted at Clemson University (SCDHEC Certified Laboratory # 39568001) using a membrane filter method based on *Standard Methods for the Examination of Water and Wastewater* 9222D (APHA, 2005). Quality assurance samples were analyzed by Goldie & Associates, Seneca, SC and the Greenville Water System Laboratory at Lake Keowee.

Source tracking methods applied included carbon source utilization based on Hartel (2002) and Hagadorn et al. (2003), fecal sterols and fluorinated whitening agent [FWA] (Fahrenfeld, 2008), and utilization of DNA-based markers (U.S. EPA, 2007).

RESULTS AND CONCLUSIONS

Sampling of Cane and Little Cane Creek watersheds in 2007 isolated several stream segments with elevated FC contamination (Table 1). The geometric mean FC concentrations of the 30-day compliance samples taken from mid-September to mid-October 2007 near the SCDHEC compliance monitoring stations (sites C3 and LC10) were 167 and 260 cfu/100 mL, respectively. This indicated that Cane Creek (C3) was in compliance, while Little Cane Creek (LC10) remained out of compliance, as of October 1, 2007. By comparison, SCDHEC's monthly monitoring data near C3 from February 2004 to February 2006, excluding dates with >0.25 in. rainfall, averaged 210 cfu/100 mL, and 125 cfu/100 mL from February 2006 to June 2008. Similarly, SCDHEC monthly data near LC10 from February 2004 to December 2005 averaged 402 cfu/100 mL, while the December 2005 to June 2008 average was 226 cfu/100 mL. These SCDHEC values supported the trend in water quality improvement observed as the grant progressed.

Stream segments showing high FC counts in 2007 were selected for re-sampling in June 2008 to update stream status and perform source tracking analyses. Sample aliquots from each sampling location were sent to three independent laboratories to perform FC counts. Results are presented as averages in Table 2. Source tracking analyses indicated that human, cattle, horse, and bird are all sources of fecal contamination in the area of interest (Table 3).

Since initial identification of problem stream segments, 15 septic systems have been repaired or replaced, and five more are approved for cost-share assistance. Two agricultural BMPs have been contracted, and another is under development. Problems discovered with the City of Walhalla sewer system have been corrected or are being repaired currently.

Table 1. 2007 fecal coliform bacteria in Cane Creek and Little Cane Creek, Oconee County, South Carolina. n = 1 to 6 events

Sampling Location	Average Fecal Coliform Concentration (cfu/100 mL)
C1	120
C1A	270
C1B	143
C1C	70
C1D	210
C2	440
C2A	180
C2B	31
C2C	349
C3	173
C3A	270
C3B	217
C3C	150
LC1	78
LC2	100
LC2A	180
LC3	150
LC3A	50
LC4	250
LC4A	160
LC5	214
LC5A	120
LC5B	50
LC5C	2,800
LC6	180
LC6A	110
LC6B	320
LC7	290
LC7A	320
LC8	850
LC9	491
LC9A	264
LC9B	452
LC9D	317
LC10	293

Table 2. Fecal coliform bacteria in Cane Creek and Little Cane Creek Watersheds, June 23, 2008.

Sampling Location	Average Fecal Coliform Concentration (cfu/100 mL)*
C1	122 (25)
C2C	240 (141)
C3B	306 (211)
LC1	300 (130)
LC2	288 (47)
LC5A	480 (564)
LC5C	47,750 (51,690)
LC6A	1,132 (1,704)
LC9	330 (410)
LC9A	203 (128)
LC9B	648 (395)
LC10	206 (109)

* Average concentration of three split samples analyzed at independent laboratories. Standard deviation provided in parentheses.

Table 3. Source tracking results in samples obtained from out-of-compliance sites in Cane Creek and Little Cane Creeks Watersheds.

Smp. Loc.	DNA-Based Methods 2007	DNA-Based Methods 2008	Carbon Assimilation Method 2008	Sterol Method 2008
C1*		C		H
C2C	H	C	H	H
C3B			H,HS	
LC1			H,HS	NT
LC2			C,H	
LC5A	C	C	C,H	NT
LC5C	C	C,H	C	NT
LC6A			H	NT
LC6B*	B			NT
LC9	C	C	C,H,HS	NT
LC9A	C	C	C,H	NT
LC9B		C	H	NT

C = cattle (possibly other ruminants); H = Human; HS = Horse (possibly goat); B = Bird; NT = Not tested
* Site not out of compliance, but of interest due to apparent sources.

Recent sampling indicates that Cane Creek is in compliance and Little Cane Creek is improving. Source control measures have apparently been effective. Preliminary source tracking results have been useful in identifying areas in need of remediation and source controls necessary, although the FWA method was not effective. Preliminary results from source tracking methods were largely in agreement. These methods may be useful in future FC TMDL studies to improve implementation time, cost effectiveness, and corrective actions. Additional sampling is planned during 2008 for source tracking and final grant source control implementation, and to document final stream status.

ACKNOWLEDGEMENTS

The authors appreciate the kind and dedicated persons within our respective organizations (FOLKS, Clemson University, U.S. EPA, ENTRIX), SCDHEC, City of Walhalla, Goldie & Associates, Greenville Water System, and cooperative land owners assisting in this project.

LITERATURE CITED

American Public Health Association (APHA), American Water Works Association, and Water Pollution Control Federation, 2005, Standard Methods for Examination of Water and Wastewater, 21st Ed.: Washington, D.C., American Public Health Association.

Fahrenfeld, N.L. 2008. Fecal Coliform Source Identification Using Chemical Tracers. [Master's Thesis]. Department of Environmental Engineering and Earth Sciences, Clemson University, 137 pp.

Hagadorn, C., J. B. Crozier, K. A. Mentz, A. M. Booth, A. K. Graves, N. J. Nelson, and R. B. Reneau Jr. 2003. Carbon Source utilization profiles as a method to identify sources of fecal pollution in water. *Journal of Applied Microbiology* 94: 792-799.

Hartel, P. G. 2002. Targeted Sampling as an alternative to establishing a permanent host origin database. *Environmental Detection News* (2) 1: 1-3.

U.S. Environmental Protection Agency (US EPA). 2005. Watershed Characterization Document for Cane and Little Cane Creeks (Hydrologic Unit Code: 03060101-050 & Stations SV-342 & SV-343) Fecal Coliform Bacteria. SCDHEC Technical Report Number: 017-05 May 2005.

U.S. Environmental Protection Agency (US EPA). 2007. Evaluation of Selected DNA-based Technology in Impaired Watersheds Impacted by Fecal Contamination from Diverse Sources. National Exposure Research Laboratory, Office of Research and Development, Ecosystems Research Division, Athens, GA 30605. EPA/600/R-07/123 December 2007.