Total Maximum Daily Load Document

Cow Castle Creek, Lower Four Hole Swamp, and Tributaries

Stations E-050 and E-100

Hydrologic Unit Codes 030502050106, 030502050107, 030502050303, 030502050304, 030502050305, 030502050306, 030502050307, 030502050308, 030502050309

Escherichia coli Bacteria Pathogen Indicator

October 2020

Bureau of Water

SCDHEC Technical Document Number: 020-2020

Healthy People. Healthy Communities.

Prepared by Susan Waldner

On reverse: Four Hole Swamp at Highway 453

Abstract

§303(d) of the Clean Water Act (CWA) and EPA's *Water Quality Planning and Management* Regulations (40 CFR Part 130) require states to develop total maximum daily loads (TMDLs) for water bodies that are included on the §303(d) list of impaired waters. A TMDL is the maximum amount of pollutant a waterbody can assimilate while meeting water quality standards for the pollutant of concern. All TMDLs include a waste load allocation (WLA) for any National Pollutant Discharge Elimination System (NPDES)-permitted discharges, a load allocation (LA) for all nonpoint sources, and an explicit and/or implicit margin of safety (MOS). This report describes the development of an *Escherichia coli (E. coli)* TMDL for impaired water quality monitoring (WQM) stations E-050 on Cow Castle Creek and E-100 on Four Hole Swamp. Water Quality monitoring site E-100 is included as impaired for recreational uses on the State's finalized 2016 §303(d) list and draft 2018 303(d) list due to excessive fecal coliform and *E. coli* bacteria. A revision is being made to an existing fecal coliform TMDL for WQM site E-050 since data continue to be collected at this site and violations continue to occur. E. coli counts exceeded the recreational use water quality standard at E-050 53% of the time. Considering data collected from 2000-2006, fecal coliform counts exceeded the water quality standard at E-100 12% of the time. This station (E-100) was placed on the 2008 303(d) list based on data collected during 2006, during which time 20% of the samples were in violation of the standard.

The watersheds draining to these sites are located in Berkeley, Dorchester, and Orangeburg Counties. Probable sources of fecal contamination include direct and indirect loading from livestock, failing septic systems, surrounding wildlife, and other agricultural activities.

The load-duration curve methodology was used to calculate existing and TMDL loads for each impaired station. Existing pollutant loadings and proposed TMDL reductions for critical hydrologic conditions are presented in Table Ab-1. Critical hydrologic conditions were defined as either moist, mid-range, or dry depending on which condition demonstrated the highest load reductions necessary to meet water quality standards. To achieve the target load (slightly less than the maximum load due to the margin of safety) for the TMDL watersheds, reductions in the existing loads of 66% at E-050 and 58% at E-100 will be necessary.

For SCDOT, existing and future NPDES MS4 permittees, compliance with terms and conditions of their NPDES permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP) and demonstrates consistency with the assumptions and requirements of the TMDL. For existing and future NPDES construction and industrial stormwater permittees, compliance with terms and conditions of their permit is effective implementation of the WLA. Required load reductions in the LA portion of this TMDL can be implemented through voluntary measures and are eligible for CWA §319 grants.

The South Carolina Department of Health and Environmental Control (SCDHEC) recognizes that adaptive management/implementation of these TMDLs might be needed to achieve the water quality standard and we are committed towards targeting the load reductions to improve water quality in the Cow Castle Creek and Lower Four Hole Swamp Watersheds. As additional data and/or information become available, it may become necessary to revise and/or modify the TMDL target accordingly.

Table Ab1. Total Maximum Daily Loads for Cow Castle Creek, Lower Four Hole Swamp and Tributaries

	Existing Load		TMDL		Margin of Safety		Waste Load Allocation (WLA)			Load Allocation (LA)		
Station	**Existing FC Load (cfu/day)**	**Existing *E. Coli* Load (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**Continuous Source *E. coli*[1] (MPN/day)**	**Non-Continuous Sources[2,3] (% Reduction)**	**Non-Continuous SCDOT[3,4] (% Reduction)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**% Reduction to Meet LA[3]**
E-050	---	5.67E+11	---	2.96E+11	---	1.44E+10	3.12E+09 (see note 1)	66%	66%	---	2.79E+11	66%
E-100	1.14E+13	9.98E+12 (see note 5)	5.08E+12	4.44E+12 (see note 5)	2.54E+11	2.16E+11 (see note 5)	7.73E+07 (see note 1)	58%	58%	4.83E+12	4.22E+12 (see note 5)	58%

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Future loadings will be developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100ml.

2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern in accordance with their NPDES Permit.

3. Percent reduction applies to existing instream *E. coli*.

4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 permit to address fecal coliform bacteria or *E. coli*, SCDOT will comply with these TMDLs and their applicable WLAs to the maximum extent practicable (MEP) as required by its MS4 permit.

5. Expressed as *E. coli* (MPN/day). Loadings are developed by applying a conversion factor to values calculated for FC bacteria. This conversion factor is derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters.

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1.0 Introduction

1.1 Background

The federal *Clean Water Act (CWA)* directs each state to review the quality of its waters every two years to determine if water quality standards are being met. If it is determined that the standard is not being met, the states are to list the impaired water body under §303(d) of the *CWA*. These impairments are then addressed by a Total Maximum Daily Load (40 CFR 130.31(a)).

A Total Maximum Daily Load document (TMDL) is a written plan and analysis to determine the maximum pollutant load a waterbody can receive and still meet applicable water quality standards. The TMDL process includes estimating pollutant loadings from all sources, linking these sources to their impacts on water quality, allocation of pollutant loads to each source, and establishment of control mechanisms to achieve water quality standards. All TMDLs include a waste load allocation (WLA) for all National Pollutant Discharge Elimination System (NPDES) permitted discharges, a load allocation (LA) for all unregulated nonpoint sources, and an explicit and/or implicit margin of safety (MOS).

Escherichia coli (E. coli) bacteria are members of the fecal coliform group of bacteria and are part of the normal flora of the gastrointestinal tract of warm-blooded animals. These bacteria play an important role in preventing the overgrowth of harmful bacteria in the gut, vitamin K production, lactose digestion, and fat metabolism. Some Shiga toxin producing strains of *E. coli*, such as O157:H7 can cause gastrointestinal illnesses, kidney failure and death. *E. coli* bacteria in surface waters are indicators of recent human or animal waste contamination and may originate from failing septic systems, agricultural runoff, and leaking sewers, among other sources (Blount, 2015, Wolfson and Harrigan, 2010).

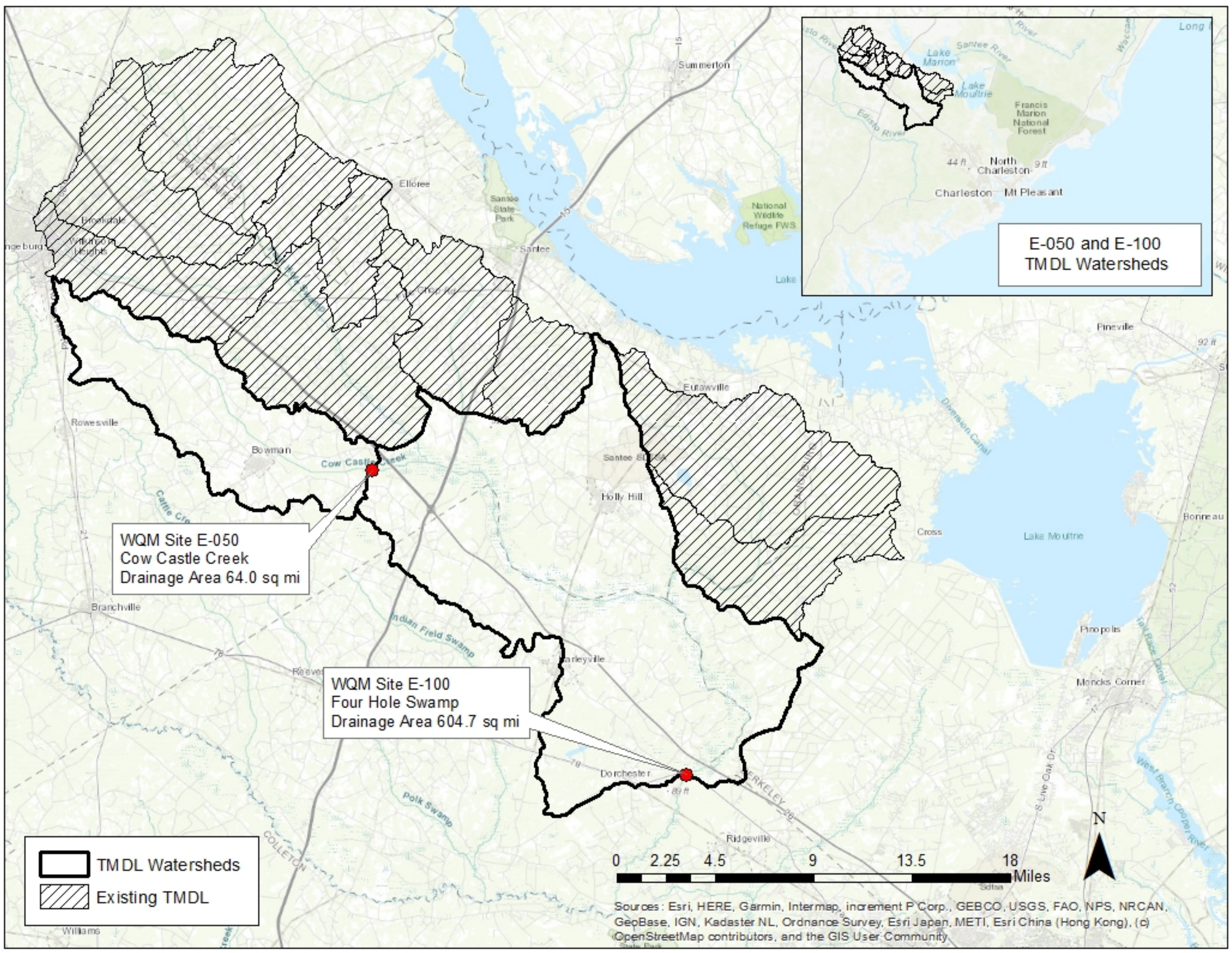
This document details the development of *E. coli* bacteria TMDLs for two water quality monitoring (WQM) stations. E-100 on Four Hole Swamp is a historical site and was sampled 1999 - 2001, and 2006. E-050 on Cow Castle Creek is an active sampling site and has been sampled since 2001.

Until 2013, SCDHEC used fecal coliform bacteria as a pathogen indicator. In 2013, SCDHEC changed the pathogen indicator used to determine support of recreational uses from fecal coliform bacteria to *E. coli.* Beginning with the development of South Carolina's 2014 §303(d) list, any site that had been determined to be impaired for freshwater recreational use based on the previous standard was listed for *E. coli* bacteria rather than fecal coliform bacteria. In this analysis, fecal coliform loading from E-100 was converted to *E. coli* loading. Data from E-050 include both fecal coliform and *E. coli*, but only the *E. coli* data were used.

Table 1. Impaired WQM Stations

Stream Name	WQM Station	Description
Cow Castle Creek	E-050	Cow Castle Creek at S-38-170
Four Hole Swamp	E-100	Four Hole Swamp at US 78

Figure 1. Cow Castle Creek and Lower Four Hole Swamp Watersheds with Locations of Impaired WQM Stations



1.2 Watershed Descriptions

For purposes of analyses of pollutant loads, sources, and subsequent allocation, the drainage areas associated with both impaired stations analyzed in this TMDL document will be addressed individually as subwatersheds. Subwatershed 050 is the area that drains to E-050, and subwatershed 100 drains to E-100. Subwatershed 100 excludes areas of the watershed with existing TMDLs (section 1.3, Figure 1) and the other subwatershed included in this TMDL document.

1.2.1 Subwatershed 050

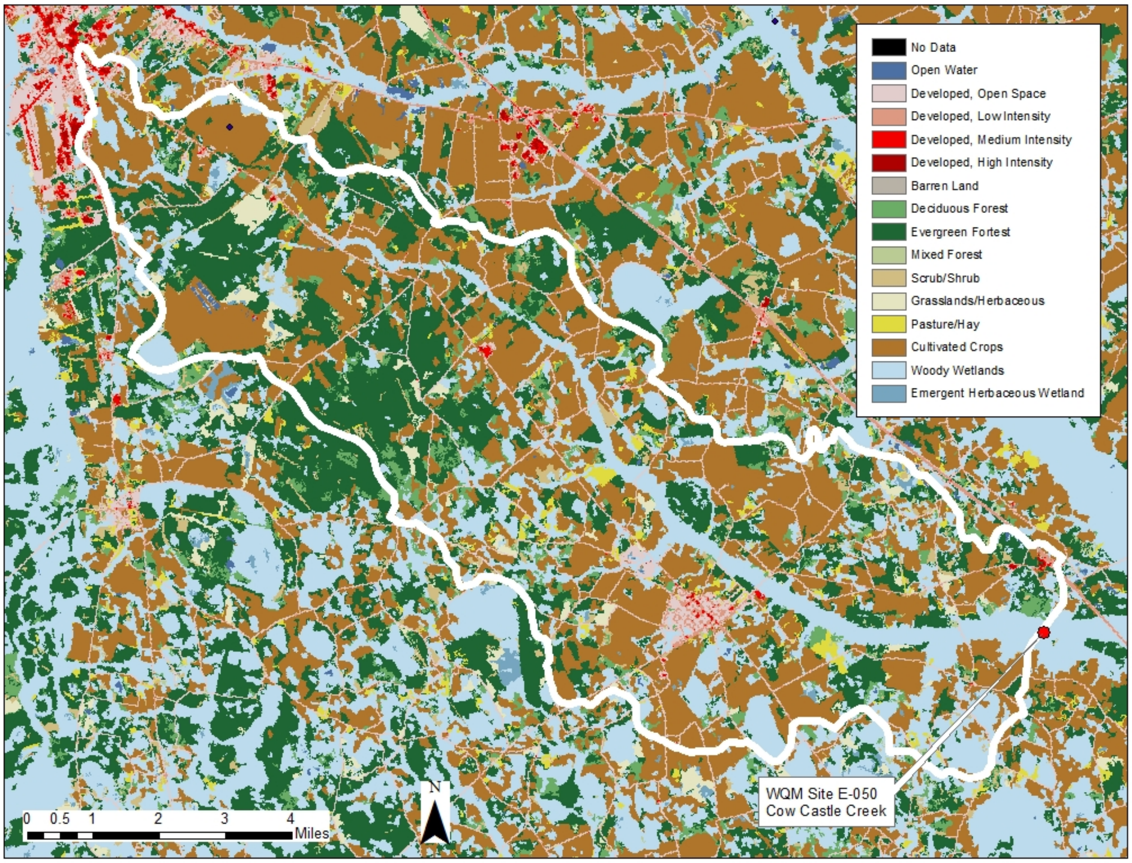
Impaired station E-050 is within the Four Hole Swamp watershed (hydrologic unit code (HUC) 0305020501) and its drainage area lies entirely within Orangeburg County. The major stream draining this area is Cow Castle Creek which receives flow from Crum Branch and Buck Branch. Flow in Cow Castle Creek originates near the City of Orangeburg and the stream runs in a southeasterly direction until its confluence with Four Hole Swamp a short distance beyond WQM site E-050. The area draining to E-050 measures 64 square miles.

The headwaters of Cow Castle Creek are in the Atlantic Southern Loam Plains ecoregion but most of the stream drains and flows through the Carolina Flatwoods ecoregion. The predominant land use categories are forested (deciduous 4.2%, evergreen 24.5%, and woody wetlands 21.0%) and agriculture (cultivated crops 36.9% and pasture/hay 1.8%). There is some development in the northwest end of the watershed near Orangeburg and in the south central part of the watershed around the Town of Bowman. A small portion (0.3 square miles) of the northwestern extent of subwatershed 050 is considered urbanized, as defined by the 2010 U.S. Census, although it remains outside of the city limits of Orangeburg. The total amount of developed land in the watershed is 6.5%. There is a moderate potential for growth due to the presence of Orangeburg, Interstate 26, and other major highways crossing the area. Significant development is planned for an adjacent watershed and this could potentially spill over into subwatershed 050 (Section 1.2.2).

Table 2. Land Use in Subwatershed 050 (National Land Cover Database (NLCD), 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	0.1	0.2%
Developed Open Space	3.2	5.0%
Developed Low Intensity	0.7	1.2%
Developed Medium Intensity	0.1	0.2%
Developed High Intensity	0.0	0.1%
Barren	0.0	0.0%
Deciduous Forest	2.7	4.2%
Evergreen Forest	15.7	24.5%
Mixed Forest	0.3	0.4%
Shrub/Scrub	1.3	2.1%
Grassland/Herbaceous	1.3	2.0%
Pasture/Hay	1.2	1.8%
Cultivated Crops	23.6	36.9%
Woody Wetlands	13.4	21.0%
Emergent Herbaceous Wetlands	0.2	0.4%
Total	64.0	100.0%

Figure 2. Land Use in Subwatershed 050 (NLCD, 2016)



1.2.2 Subwatershed 100

The drainage area of impaired station E-100 lies mostly within the Lower Four Hole Swamp HUC 0305020503 and occupies portions of Berkeley, Dorchester, and Orangeburg counties. A total area of 604.7 square miles drains to WQM station E-100. This drainage area includes several existing approved TMDL watersheds as well as the other impaired station assessed in this TMDL document (Figure 1). When these areas are subtracted, the drainage area for subwatershed 100 is 205.6 square miles.

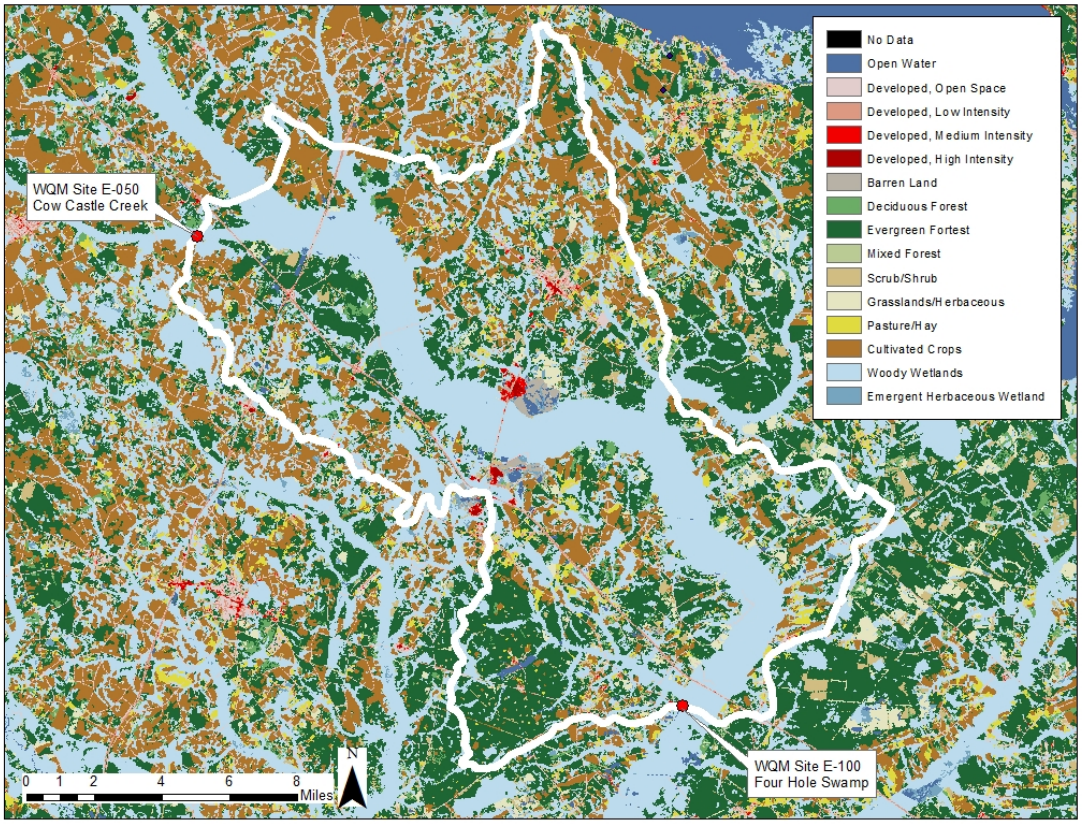
This subwatershed is within the Carolina Flatwoods and the Mid-Atlantic Floodplains and Low Terraces ecoregions. Land use in this subwatershed (excluding the existing TMDL watersheds and subwatershed 050) is primarily forested (deciduous 1.8%, evergreen 26.8%, and woody wetlands 40.5%). The amount of developed land is 5.9% of the total. The Town of Holly Hill and portions of Harleyville and Dorchester are within this subwatershed.

There is the potential for major growth in the upper portion of this watershed due to a large planned intermodal port which is expected to create up to 10,000 jobs. Most of the growth is to be focused in the triangle of land bounded by U.S. Highway 301 and Interstates 26 and 95. The lower portion of the watershed is experiencing growth as well as housing spreads outward from Charleston and Summerville and industry moves to the area.

Table 3. Land Use in Subwatershed 100 (NLCD, 2016)

Land Use Description	Area (Square Miles)	Percent of Total
Open Water	1.5	0.8%
Developed Open Space	8.3	4.0%
Developed Low Intensity	3.0	1.5%
Developed Medium Intensity	0.5	0.3%
Developed High Intensity	0.3	0.1%
Barren	1.3	0.6%
Deciduous Forest	3.8	1.8%
Evergreen Forest	55.2	26.8%
Mixed Forest	0.9	0.4%
Shrub/Scrub	4.3	2.1%
Grassland/Herbaceous	3.8	1.8%
Pasture/Hay	5.5	2.7%
Cultivated Crops	33.1	16.1%
Woody Wetlands	83.3	40.5%
Emergent Herbaceous Wetlands	0.9	0.4%
Total	205.6	100.0%

Figure 3. Land Use in Subwatershed 100 (NLCD, 2016)



1.3 Existing Total Maximum Daily Loads for the Four Hole Swamp Area

In 2005, TMDLs were approved for six fecal coliform-impaired WQM sites in the Four Hole Swamp drainage area (SCDHEC Technical Document 015-06, Four Hole Swamp and Tributaries, https://www.scdhec.gov/environment/your-water-coast/approved-tmdls). All six WQM sites are in watersheds that drain to the areas addressed in this TMDL document (Figure 1, Table 4). Sampling at three of these sites was discontinued in 2009 (E-051, E-059 and E-076). Sampling at E-022 was discontinued in 2010 and sampling at E-052 was discontinued in 2009. There is one additional year of data at E-052 (2017) but this is not sufficient to revise the existing TMDL. Because there is little or no new data with which to reassess these areas, these TMDLs will not be revised and their load, wasteload, and margin of safety allocations remain in effect.

The WQM site on Cow Castle Creek (E-050) was also included in the approved TMDL document 015-06. Sampling has continued at this site and violations of the water quality standard for recreational uses persist. Since there is new data to evaluate, the TMDL for this WQM site will be revised.

Six other impaired WQM sites in watersheds draining to E-100 were more recently evaluated in two TMDL documents (SCDHEC Technical Documents 1101-19 Dean Swamp and Sandy Run; and 010-2020 Upper Four Hole Swamp and Tributaries: https://www.scdhec.gov/environment/your-water-coast/approved-tmdls).

The existing TMDL evaluations showed that violations of the fecal coliform and *E. coli* standards occurred under a range of flow conditions (high, average, and low flow) indicating that there are a variety of sources for the bacteria.

Table 4. Existing TMDL Sites within the Drainage Area of this TMDL Assessment

WQM Station	Location	Year Approved	SCDHEC Document
E-022	Gramling Creek on SC 33	2005	015-06
E-050	Cow Castle Creek at S-38-170	2005	015-06
E-051	Providence Swamp at US 176	2005	015-06
E-052	Horse Range Swamp at US 176	2005	015-06
E-059	Four Hole Swamp at S-38-50	2005	015-06
E-076	Tributary to Gramling Creek at SC 33	2005	015-06
RS-01036	Goodbys Swamp at US 176	2020	010-2020
RS-04537	Unnamed Tributary to Four Hole Swamp at S-38-92	2020	010-2020
RS-07213	Mill Branch at S-38-492	2020	010-2020
E-111	Four Hole Swamp at SC 210	2020	010-2020
E-030	Dean Swamp at US 78	2019	1101-19
E-115	Sandy Run at Cement Bridge Road	2019	1101-19

1.4 Water Quality Standard

The impaired streams addressed by this TMDL document are designated as Class Freshwater (FW) (Cow Castle Creek) and FW* (Four Hole Swamp). Both are defined in South Carolina Regulation 61-69 (2012):

“Freshwaters are suitable for primary and secondary contact recreation and as a source for drinking water supply after conventional treatment in accordance with the requirements of the Department. Suitable for fishing and the survival and propagation of a balanced aquatic community of fauna and flora. Suitable also for industrial and agricultural uses”.

South Carolina’s water quality standard (WQS) for recreational use in freshwater is *E. coli* (R.61-68, 2014):

“Not to exceed a geometric mean of 126/100 ml based on at least four samples collected from a given sampling site over a 30 day period, nor shall a single sample maximum exceed 349/100 ml”

Prior to February 28, 2013, South Carolina’s WQS for recreational use was fecal coliform (FC) bacteria:

“Not to exceed a geometric mean of 200/100 mL based on five consecutive samples during any 30 day period; nor shall more than 10% of the total samples during any 30 day period exceed 400/100mL.”

In 1986, the United States Environmental Protection Agency (EPA) documented that *E. coli* and enterococcal species are better indicators than the FC bacteria group for predicting the presence of gastroenteritis-causing pathogens in freshwaters. The EPA study was based on data collected in areas where swimmers were directly exposed in freshwater lakes with established public swimming areas. The results indicated that *Enterococcus* and *E. coli* are more specific to sewage and other fecal sources than the FC bacteria group. In light of this information, EPA recommended the use of either *E. coli* or *Enterococcus* as the pathogen indicator for freshwaters.

To determine which of these pathogen indicators was better suited in South Carolina as the recreational use water quality standard in freshwaters, SCDHEC designed a pathogen indicator study, conducted in 2009. Weekly water samples were collected from 73 stations statewide and analyzed for *E. coli*, *Enterococcus*, and for FC bacteria. The study results showed *E. coli* is a better indicator for predicting the presence of pathogens in South Carolina freshwaters.

During 2012, following the public participation and public comment period and legislative processes, SCDHEC submitted a proposed amendment to EPA to change the pathogen indicator from FC bacteria to *E. coli* in R. 61-68. The proposed amendment was approved by EPA on February 28, 2013. Beginning on this date, *E. coli* as a pathogen indicator was promulgated in R. 61-68 and is now the applicable water quality standard for recreational use in freshwaters.

Beginning with the 2014 303(d) list of impaired waters, sites that had previously been listed as impaired for recreational use by FC bacteria exceedences would now be listed as impaired by *E. coli*. Once sufficient *E. coli* data are collected from impaired stations, future TMDLs will be calculated based on *E. coli* data. Until this time, TMDLs for FC impaired stations can be calculated using FC data. These FC TMDLs can then be converted to *E. coli* TMDLs by multiplying the FC TMDL by 0.8725. This ratio was derived by dividing the current single sample maximum WQS for *E. coli*, 349 MPN/100 ml, by the former single sample maximum WQS for FC bacteria, 400 cfu/100 ml.

2.0 Water Quality Assessment

Two WQM stations are addressed in this TMDL document. One of these (E-100 on Four Hole Swamp) is a historical site sampled beginning 1999 through 2001 and again in 2006. The other (E-050 on Cow Castle Creek) is an active site at which sampling continues. Both sites were included in the state's final 2016 Integrated Report and the draft 2018 Integrated Report due to *E. coli* exceedences.

Station E-100 was included on the state's 303(d) list for the first time in 2008 for FC exceedences. This station was sampled when the standard for freshwater recreational uses was FC bacteria. Since 2013 when the freshwater indicator changed from FC bacteria to *E. coli*, this site has been listed for *E. coli* exceedences. The TMDL for E-100 was calculated using FC data beginning with that collected on 1/2000. The loads, wasteloads, and margins of safety were converted to the *E. coli* standard in accordance with the description above.

Station E-050 has been included on the state's 303(d) list since at least 1998. Sampling data are available from January 2001 to present. The TMDL for E-050 was calculated using only *E. coli* sampling data collected from 2/2013 through 1/2018.

There was an additional site sampled in subwatershed 050: RS-09277 on Cow Castle Creek at S-38-198. This random station was sampled in 2009 and it also violated the WQS for recreational uses. Since this site was located within an existing TMDL, it has been included in Appendix D of the Integrated Report (SC Waters with an Approved TMDL) rather than the list of impaired waters. Because the area draining to this station will be assessed along with rest of subwatershed 050, its data will not be analyzed separately or included with the assessment of E-050.

For recreational use, if greater than 10% of the monthly geometric mean of available data collected during an assessment period exceeds the criterion, the station is included on South Carolina's §303(d) list. If sufficient data are not available to calculate a geometric mean, then the available sample results are compared against the single sample maximum (SSM) criterion. If greater than 10% of these samples exceed this criterion then the station is included on South Carolina's §303(d) list as not supporting recreational use. Table 5 provides a summary of the number of samples collected, number of exceedences, and the percentage of samples exceeding the standard.

Table 5. Exceedence Summary for WQM Stations E-050 and E-100

Station	Waterbody	Number of Samples	Number Exceeding	Percent Exceeding	Year(s) Sampled
E-050	Cow Castle Creek	36	19	53%	2013-2018
E-100	Four Hole Swamp	34	4	12%	2000-2001, 2006

3.0 Source Assessment

While there are assays available for specific human pathogens that may be present in surface water, it is not possible to test for every potential pathogenic organism. For this reason, indicator bacteria (such as *E. coli*) are used to indicate the possible presence of human pathogens. Indicator bacteria are easy to measure, persist in surface waters for a similar or longer length of time, and have similar sources as pathogens of concern. There are also pathogenic forms of *E. coli*. These may be found in the gastrointestinal tracts of ruminant animals such as cattle, goats, sheep, deer, and elk, and can produce toxins (Shiga toxin-producing *E. coli* or STEC). Of these, cattle are the major source for human illnesses. A STEC infection may occur through accidental ingestion of water (through recreational contact) contaminated with feces.

There are many potential sources of pathogens in surface waters. In general, these sources may be classified as point and nonpoint sources. With the implementation of technology-based controls, pollution from continuous point sources, such as factories and wastewater treatment facilities, has been greatly reduced. These point sources are required by the CWA to obtain a NPDES permit and in South Carolina, NPDES permits require that dischargers of sanitary wastewater meet the state standard for the relevant pathogen indicator at the point of discharge. Municipal and private sanitary wastewater treatment facilities may occasionally be sources of pathogens. However, if these facilities are discharging wastewater that meets their permit limits, they cannot be causing an impairment. If any of these facilities are not meeting their permit limits, enforcement actions/mechanisms are required.

Municipal Separate Storm Sewer Systems (MS4s) and stormwater discharges from regulated construction or industrial sites are considered non-continuous point sources. These sources are required to obtain NPDES discharge permits for industrial and construction activities under the NPDES stormwater regulations. They are also required to comply with the state standard for the pollutant(s) of concern. If

MS4s and discharges from construction sites meet the percentage reduction or the water quality standard as prescribed in Section 5 of this TMDL development document and required in their MS4 permits, they should not be causing or contributing to an instream pathogen impairment.

Nonpoint sources of pollution come from many sources. It is usually the result of overland runoff and as such, may be the predominate source in wet conditions. Malfunctioning septic tanks, sanitary sewer overflows, pet waste, and poorly managed livestock operations are some of the potential sources of pathogens in surface water.

3.1 Point Sources

Point sources are defined as pollutant loads discharged at a specific location from pipes, outfalls, and conveyance channels from either municipal wastewater treatment plants, industrial waste treatment facilities, or regulated storm water discharges. Point sources can also include pollutant loads contributed by tributaries to the main receiving water stream or river. Point sources can be further broken down into continuous and non-continuous.

3.1.1 Continuous Point Sources

There are five NPDES-permitted continuous point sources in the watersheds draining to E-050 and E-100 that can be expected to discharge *E. coli* bacteria. Two of these (SC0029645 and SCG570036) are in the previously approved TMDL watersheds and were assigned wasteload allocations that are still valid. The third facility is a municipal wastewater treatment plant serving the Town of Bowman in subwatershed 050 (SC0040037) which is permitted to discharge up to 0.236 MGD of treated sanitary wastewater to Cow Castle Creek. The fourth and fifth are industrial facilities in subwatershed 100 that operate mines and manufacture cement. Holcim Cement operates under permit number SC0002992 and has a small sanitary component to their effluent which is discharged to Home Branch. Giant Cement operates under permit number SC0022667 and it also has a small sanitary component to their effluent which is discharged to Four Hole Swamp (Table 6, Figure 4).

In South Carolina, NPDES permitees discharging sanitary wastewater must meet the water quality criteria for *E. coli* bacteria at the point of discharge (a daily maximum of 349 MPN/100ml, and a 30-day maximum geometric mean of no more than 126 MPN/100ml). As such, a facility meeting their discharge limits would not cause a violation in the stream.

The Bowman WWTP, while averaging a discharge flow that is less than half of the design flow (0.1 MGD during the period 2000 through 2017), has had several instances of excess E. coli in their discharge. There were three violations of their limit in a six month period (6/2019 through 11/2019) and as such, the facility has been referred for compliance and enforcement actions.

Any future NPDES-permitted dischargers of *E. coli* and other FC bacteria in this watershed will be required to implement the WLA and demonstrate consistency with the assumptions and requirements of this TMDL.

Figure 4. Location of NPDES Permitted Wastewater Treatment Plants

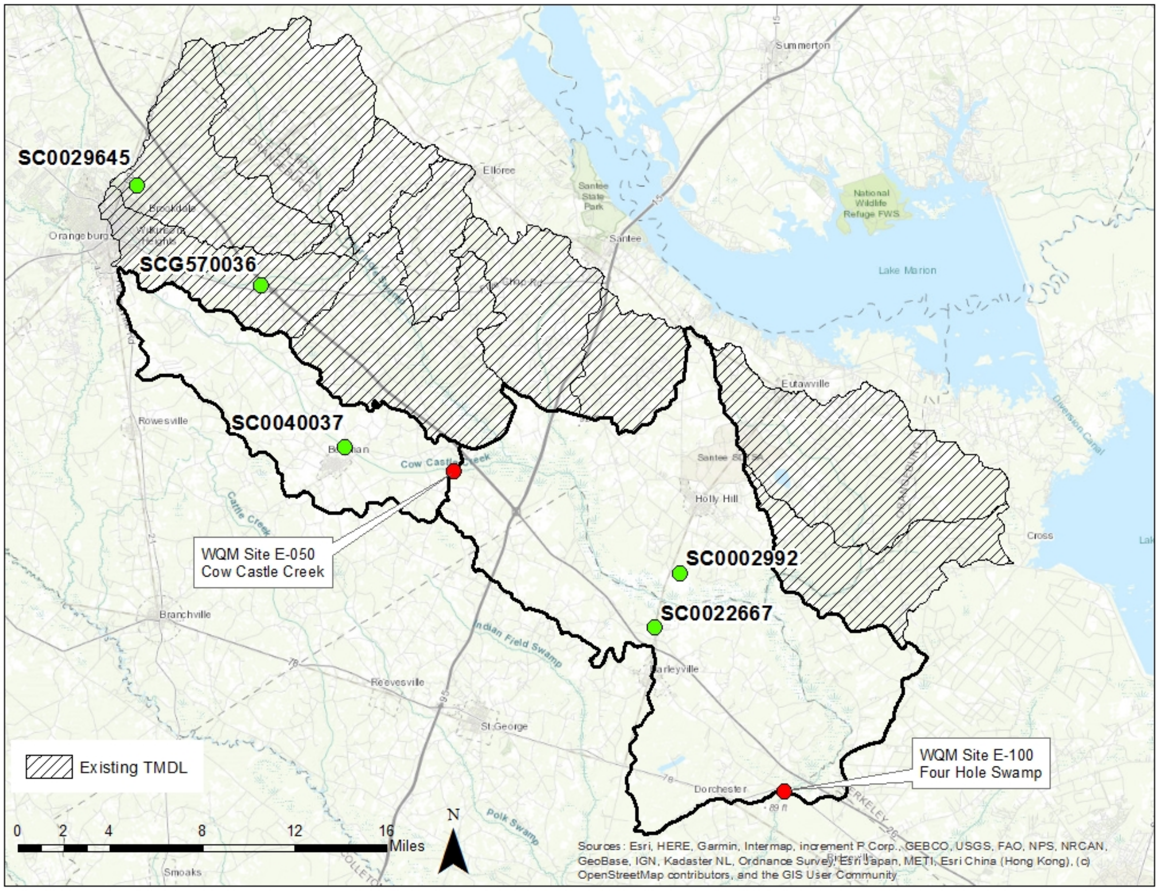


Table 6. NPDES Facilities Permitted to Discharge *E. coli* in the TMDL Subwatersheds

Facility Name	NPDES Permit	Receiving Stream	Subwatershed
Town of Bowman	SC0040037	Cow Castle Creek	050
Holcim Cement	SC0002992	Home Branch	100
Giant Cement	SC0022667	Four Hole Swamp	100

3.1.2 Non-Continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial discharges covered under permit numbers beginning with SCS and SCR and regulated under SC *Water Pollution Control Permits* Regulation R61-9, §122.26(b)(4),(7),(14) - (21) (SCDHEC, 2011). All regulated MS4 entities have the potential to contribute FC bacteria loadings, including *E. coli* and other pathogens in the delineated drainage area used in the development of these TMDLs and as such may be subject to the WLA portion of the TMDL. A high percentage of developed land within a watershed suggests the potential for impacts from non-continuous point sources (as well as other sources). Developed land use in subwatershed 050 is 6.5% of the total (4.0 square miles) and in subwatershed 100 it is 5.9% of the total (12.1 square miles) (Table 7).

The South Carolina Department of Transportation (SCDOT) is currently the only designated MS4 within both subwatersheds. The SCDOT operates under NPDES MS4 Permit SCS040001 and owns and operates facilities and roads within the watershed. However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.

Based on information available at the time of this TMDL development there is one SCDOT facility in the TMDL drainage area. This is the SCDOT District 7 Office at 1720 Charleston Highway, Orangeburg, approximately half of which lies within subwatershed 050. According to the SCDOT website, there are two highway rest areas located within the area draining to E-100. Both rest areas are located within watersheds with existing TMDLs, however.

Industrial facilities that have the potential to cause or contribute to a violation of a water quality standard due to storm water discharge are covered by the NPDES Storm Water Industrial General Permit (SCR000000). Construction activities are usually covered by the NPDES Storm Water Construction General Permit SCR100000. Where construction has the potential to affect the water quality of a water body with a TMDL, the Storm Water Pollution Prevention Plan (SWPPP) for the site must address any pollutants of concern and adhere to any waste load allocations in the TMDL. Note that there may be other stormwater discharges not covered under permits numbered SCS and SCR that occur in the referenced watershed. These activities are not subject to the WLA portion of the TMDL.

The City of Orangeburg urbanized areais considered a potentially designated MS4. ILike regulated MS4s, potentially designated MS4 entities (as listed in 64 FR, 235, P.68837) or other unregulated MS4 communities located in the Cow Castle Creek and Lower Four Hole Swamp watersheds and surrounding watersheds may have the potential to contribute *E. coli* and other FC bacteria in stormwater runoff. These unregulated entities are subject to the LA for the purposes of this TMDL document.

Sanitary sewer overflows (SSOs) are considered non-continuous point sources. SSOs to surface waters have the potential to severely impact water quality. It is the responsibility of the NPDES wastewater discharger, or collection system operator (for non-permitted ‘collection only’ systems), to ensure that releases do not occur. Unfortunately, releases to surface waters from SSOs are not always preventable or reported. Portions of subwatersheds 050 and 100 are served by municipal wastewater treatment plants (WWTP). Sewer lines are present and therefore the potential for a SSO exists.

The Department acknowledges that progress with the assumptions and requirements of the TMDL by MS4s is expected to take one or more permit iteration. Progress towards achieving the WLA reduction for the TMDL may constitute MS4 compliance with its SWMP, provided the Maximum Extent Possible (MEP) definition is met, even where the numeric percent reduction may not be achieved in the interim.

Table 7. Developed Area within Each Subwatershed

WQM Station	Drainage Area (Square Miles)	Total Developed Area (Square Miles)	Percent Developed Area
E-050	64.0	4.0	6.5%
E-100*	205.6	12.1	5.9%

*Drainage area excludes existing TMDL watersheds and the watershed associated with the other WQM station in this TMDL

3.2 Nonpoint Sources

Nonpoint source pollution is defined as pollution that is not released through pipes but rather originates from multiple sources over a relatively large area. Nonpoint source pollution may result from activities related to land or water use such as failing septic tanks, improper animal-keeping practices, agriculture, forestry practices, wildlife, and urban and rural runoff.

Wildlife, agricultural activities, grazing animals, malfunctioning septic tanks, and other nonpoint source contributors located within unregulated areas (outside the regulated MS4 area) may contribute to *E. coli* in the Cow Castle Creek and Lower Four Hole Swamp watershed. Nonpoint sources located in unregulated areas are subject to the LA and not the WLA of the TMDL.

Nonpoint source contributions to *E. coli* may be expected to increase in response to rainfall as runoff washes pollutants from the land into waterways. Because of this, a strong positive correlation between rainfall and bacteria concentrations may indicate that nonpoint sources are predominantly responsible for bacteria exceedences (Table 8). In subwatershed 050 there was a positive relationship between precipitation and bacteria concentration with a coefficient of determination (r^2) of 0.43 and a correlation coefficient (r) of 0.66 (Figures 5 and 6). At WQM station E-100, there was also positive correlation between rainfall and bacteria amounts with a coefficient of determination of 0.38 and a correlation coefficient of 0.61 (Figures 7 and 8).

Figure 5. Correlation Between Rainfall and *E. coli* at E-050

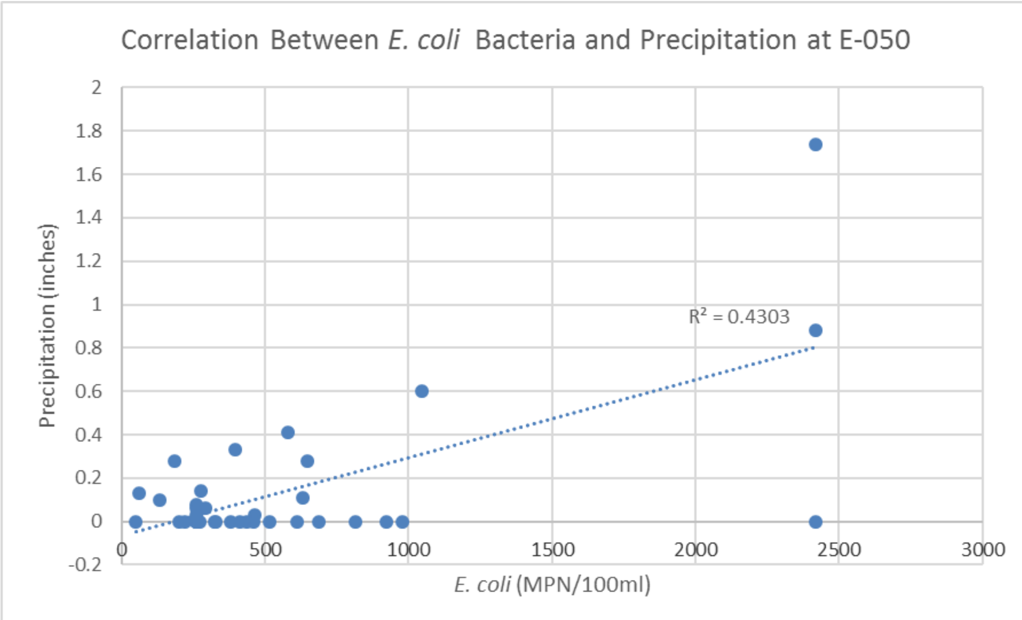


Figure 6. *E. Coli* and Precipitation at E-050

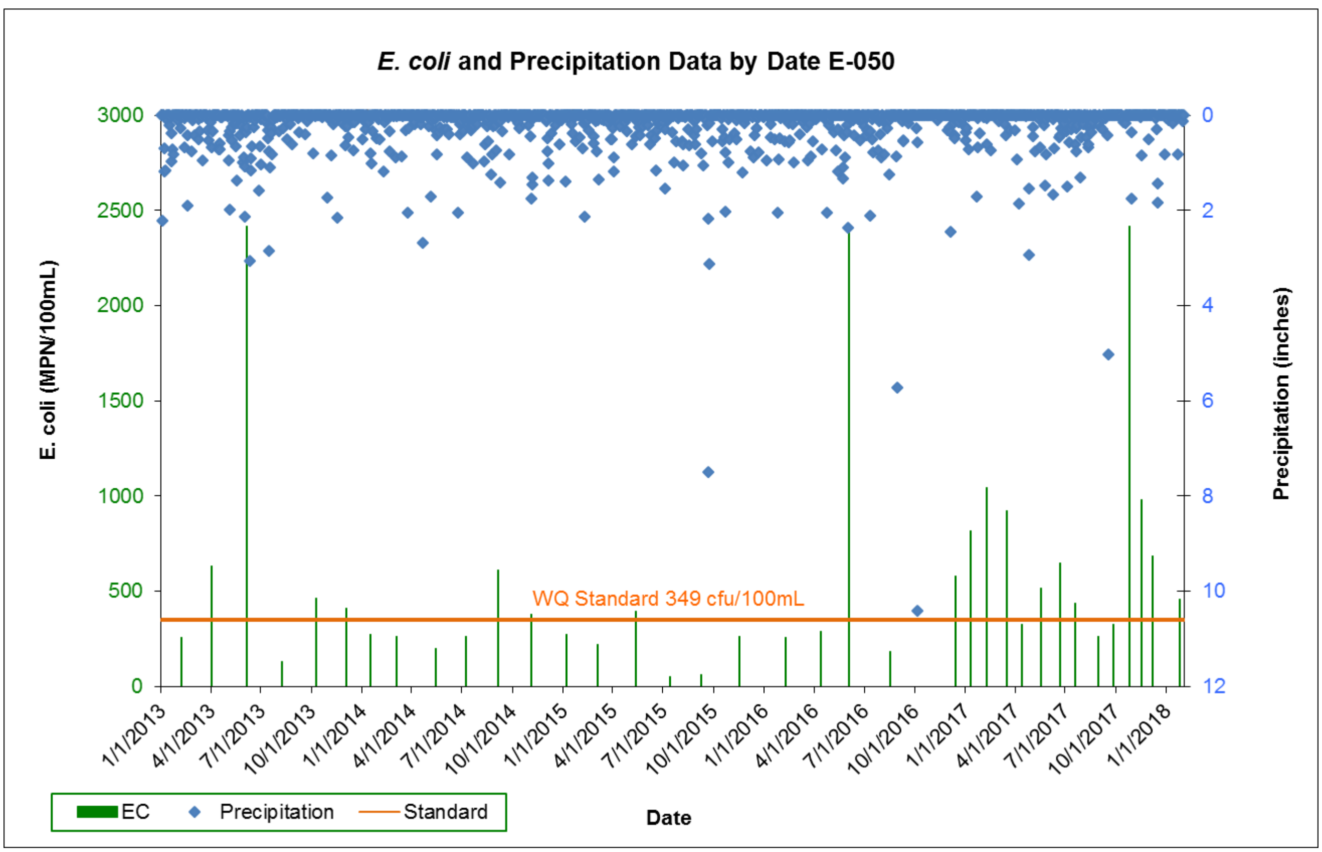


Figure 7. Correlation between Rainfall and Fecal Coliform Bacteria at E-100

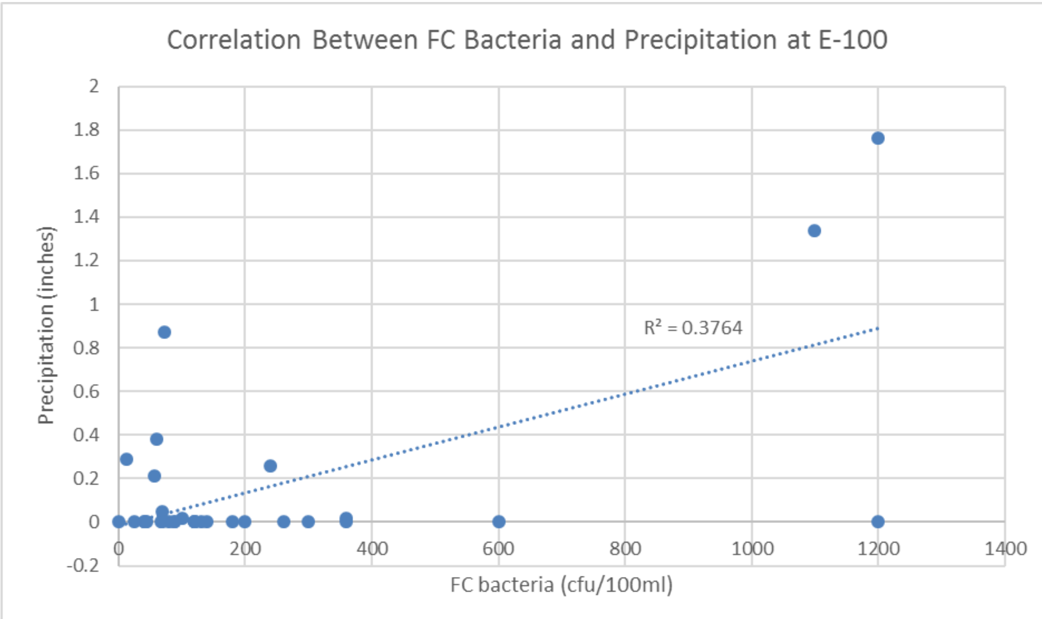


Figure 8. Fecal Coliform Bacteria and Precipitation E-100

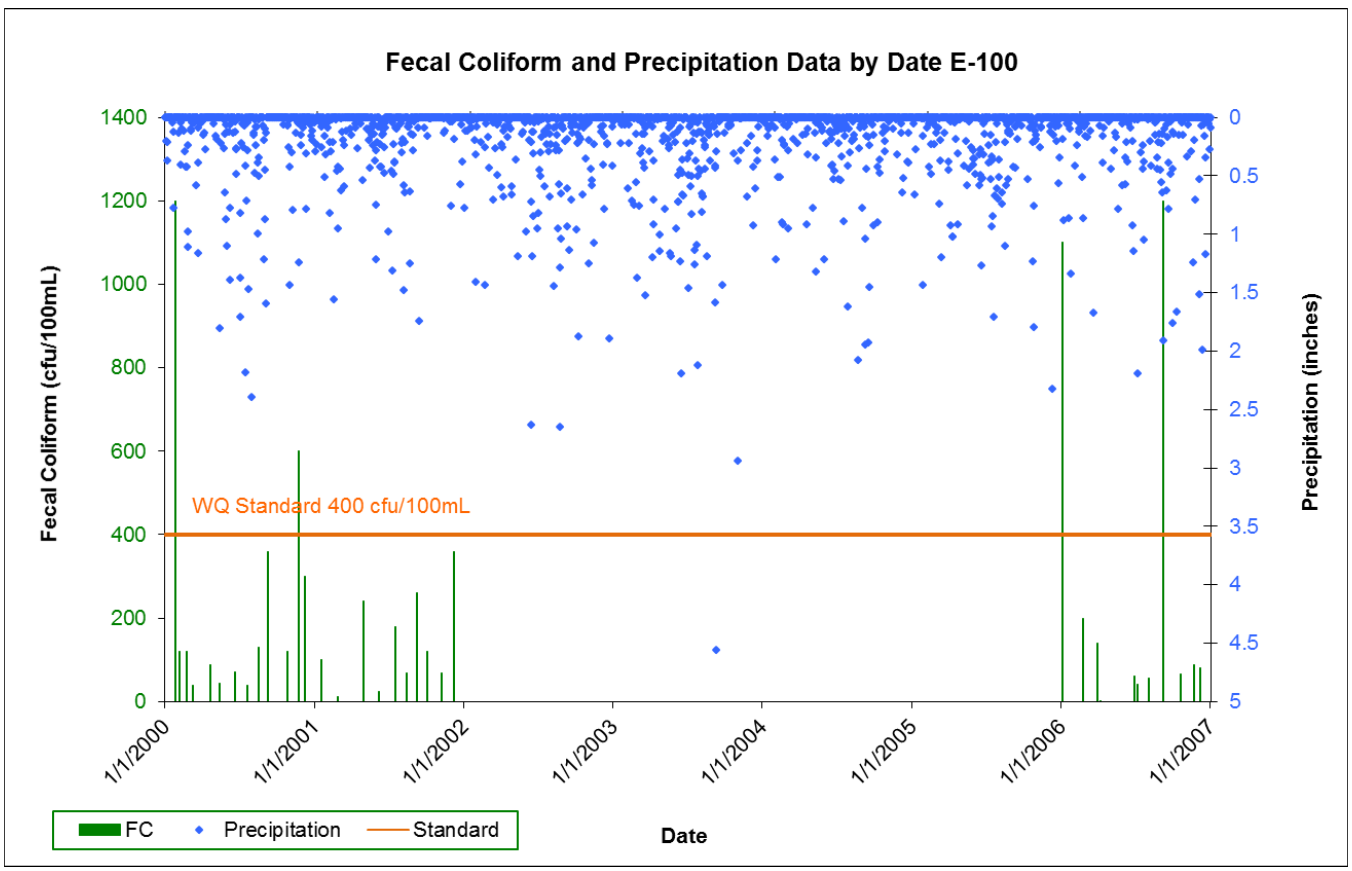


Table 8. Correlations Between Precipitation and Bacteria

Station	Waterbody	Correlation Coefficient (r)	Coefficient of Determination (r^2)
E-050	Cow Castle Creek	0.66	0.43
E-100	Four Hole Swamp	0.61	0.38

3.2.1 Wildlife

Wildlife can contribute to *E. coli* and other FC bacteria found in waterways. Wildlife inhabiting this area includes deer, squirrels, raccoons, opossums, and a variety of birds. Wildlife feces may be deposited directly into surface waters or may be carried into nearby streams by runoff following rainfall. According to a study conducted by South Carolina Department of Natural Resources (SCDNR) in 2013 and GIS analysis, the deer population within subwatershed 050 is between 1,920 and 2,880. The deer population of subwatershed 100 ranges from 7,605 to over 9,250. The SCDNR study estimated deer density based on suitable habitat (forests, croplands, and pastures). The FC bacteria production rate for deer has been shown to be 347 x 10^6 cfu/head-day in a study conducted by Yagow (1999), of which only a portion will enter the water. Wildlife may contribute a significant portion of the overall bacterial load within this mostly-rural watershed.

3.2.2 Agriculture

Agricultural activities that involve livestock or animal wastes are potential sources of pathogen contamination of surface waters. Feces can enter the waterway via runoff from the land or by direct deposition into the stream. Agricultural activities may represent a significant source of bacteria due to the large numbers of bacteria associated with animal waste.

3.2.2.1 Agricultural Animal Facilities

Owners/operators of most commercial animal growing operations are required by SC Regulation 61-43, *Standards for the Permitting of Agricultural Animal Facilities*, to obtain permits for the handling, storage, treatment (if necessary) and disposal of the manure, litter and dead animals generated at their facilities (SCDHEC, 2002). The requirements of R. 61-43 are designed to protect water quality, therefore there is a reasonable assurance that facilities operating in compliance with this regulation would not contribute to downstream water quality impairments. The state of South Carolina does not have any confined animal feeding operations (CAFOs) under NPDES coverage at this time; however, the state does have permitted animal feeding operations (AFOs) covered under R. 61-43. These permitted operations are not allowed to discharge to waters of the state and are covered under 'no discharge' (ND) permits. Discharges from these operations to waters of the state are illegal and are subject to enforcement actions by SCDHEC.

There are many animal feeding operations within the two subwatersheds evaluated in this TMDL document. They have a combined potential capacity to house over two million animals including chickens, hogs, quail, turkeys, and dairy cattle. These facilities include regulated structures and activities, including land application of manure (manure utilization areas) (Figure 9, Table 9).

Figure 9. Locations of AFO Manure Land Application Sites

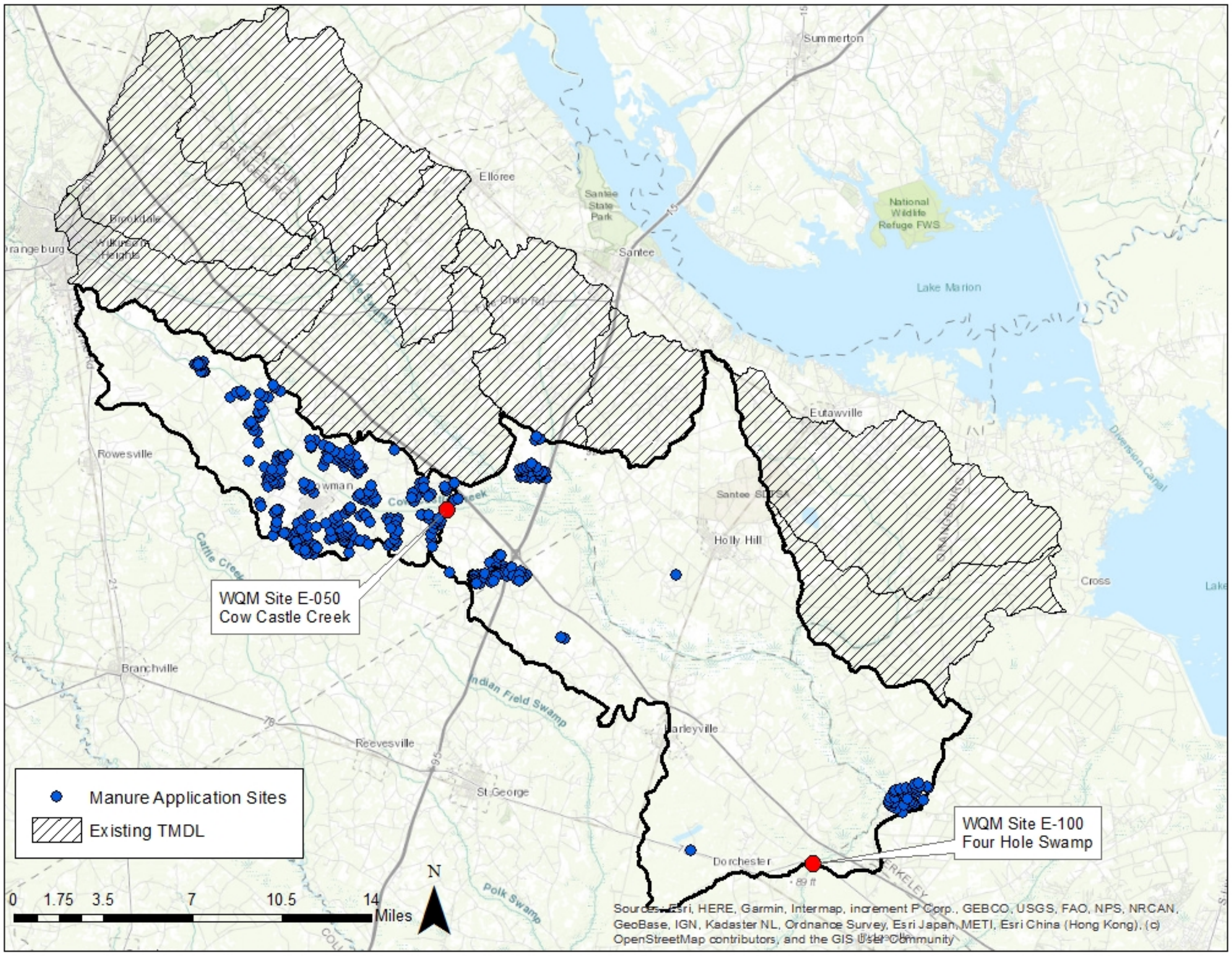


Table 9. AFO Permits in the TMDL Watersheds

Permit Number	Animal Type	AFO Size	Capacity (Maximum Number of Animals)
ND0000795	DAIRY	SMALL	300
ND0000809	DAIRY	MEDIUM	275
ND0012335	DAIRY	MEDIUM	650
ND0016829	DAIRY	MEDIUM	700
ND0060658	DAIRY	SMALL	240
ND0073431	DAIRY	MEDIUM	270
ND0068675	POULTRY (BROILERS)	MEDIUM	79000
ND0069213	POULTRY (BROILERS)	LARGE	192000
ND0069973	POULTRY (BROILERS)	LARGE	150000
ND0069981	POULTRY (BROILERS)	MEDIUM	118000
ND0069990	POULTRY (BROILERS)	MEDIUM	76000
ND0071331	POULTRY (BROILERS)	LARGE	94400
ND0073415	POULTRY (BROILERS)	SMALL	26828
ND0077461	POULTRY (BROILERS)	MEDIUM	43500
ND0079251	POULTRY (BROILERS)	MEDIUM	108000
ND0079545	POULTRY (BROILERS)	MEDIUM	108000
ND0079758	POULTRY (BROILERS)	LARGE	150000
ND0079936	POULTRY (BROILERS)	MEDIUM	114000
ND0080306	POULTRY (BROILERS)	LARGE	188000
ND0080357	POULTRY (BROILERS)	LARGE	162000
ND0081477	POULTRY (BROILERS)	LARGE	134000
ND0081833	POULTRY (BROILERS)	LARGE	148000
ND0083801	POULTRY (BROILERS)	MEDIUM	112000
ND0083313	POULTRY (LAYERS)	LARGE	120000
ND0007188	SWINE	SMALL	500
ND0064581	TURKEY, QUAIL	N/A	11050
Total			2,137,713

3.2.2.2 Grazing Livestock

Livestock, especially cattle, are frequently a contributor of *E. coli* and other FC bacteria in streams. Cattle on average produce approximately 1.0E+11 cfu/day per animal of FC bacteria (ASAE 1998). Grazing cattle and other livestock may contaminate streams with bacteria indirectly by runoff from pastures or directly by defecating into streams and ponds. Direct loading by cattle or other livestock to surface waters within the TMDL watersheds is a possible contributing source of *E. coli* and other FC bacteria. The grazing of livestock in pastures is not regulated by SCDHEC.

The United States Department of Agriculture's National Agricultural Statistics Service reported 1,936 cattle in Berkeley County, 3,946 cattle in Dorchester County, and 12,670 cattle in Orangeburg County in 2017 (USDA 2019). Assuming an even distribution across the hay / pastureland in the counties, subwatershed 050 contains 564, and subwatershed 100 contains 1,716 head of cattle. These cattle can be expected to contribute up to 2.3E+14 cfu fecal coliform bacteria per day to the entire watershed, some fraction of which may enter the waterways (Tables 10, 11).

The NLCD land classification 'pasture / hay' includes grazing land (pasture) as well as land planted for seed or hay crops (hay). The latter will be harvested and is not grazed. Also, not all cattle counted by the USDA census are grazed. Dairy cattle and feedlot cattle are often confined and would therefore not be evenly distributed across the pasture / hay land. For these reasons, the calculations provide only a rough estimate of the cattle population.

The Town of Bowman (subwatershed 050) calls itself the "dairy capital" of South Carolina and many instances of grazing were observed in this area during a site visit to the area. However, no livestock were observed in or adjacent to streams or ponds. In addition to dairy cows, beef cattle, goats and a few horses were observed in subwatersheds 050 and 100. All the animals appeared to be fenced out of waterways (Appendix C).

Table 10. Grazing Cattle per Acre of Pasture/Hay County-wide

County	Number of Cattle	Acres Pasture-Hay	Cattle/Acre Pasture-Hay
Berkeley	1,936	15,757	0.12
Dorchester	3,946	9,779	0.40
Orangeburg	12,670	16,818	0.75

Table 11. Grazing Cattle and Bacteria Produced in Each Subwatershed

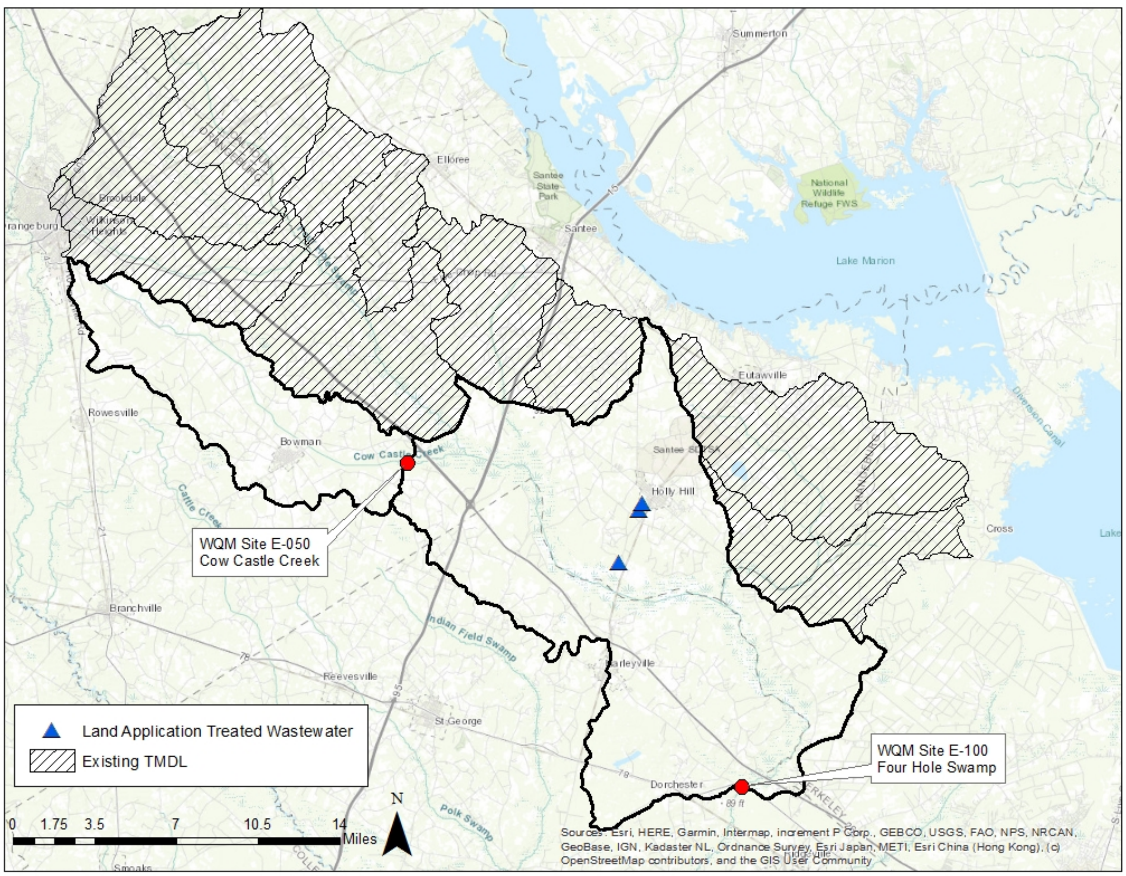
<table>
<tr><th>WQM Station</th><th>County</th><th>Pasture-Hay Acres</th><th>Cattle /Acre Pasture-Hay</th><th>Number of Cattle Grazing in Subwatershed</th><th>Bacteria Produced in Subwatershed (cfu/day)</th></tr>
<tr><td>E-050</td><td>Orangeburg County</td><td>749</td><td>0.75</td><td>564</td><td>5.6E+13</td></tr>
<tr><td rowspan="3">E-100</td><td>Berkeley County</td><td>680</td><td>0.12</td><td>82</td><td rowspan="3">1.7E+14</td></tr>
<tr><td>Dorchester County</td><td>1488</td><td>0.40</td><td>595</td></tr>
<tr><td>Orangeburg County</td><td>1386</td><td>0.75</td><td>1039</td></tr>
</table>

3.2.3 Land Application of Industrial, Domestic Sludge, or Treated Wastewater

NPDES-permitted industrial and domestic wastewater treatment processes may generate solid waste bi-products known as sludge. In some cases, facilities may be permitted to apply sludge to land at designated locations and under specific conditions. There are also some NPDES-permitted facilities authorized to apply treated effluent to land at designated locations and under specific conditions. Land application permits for industrial and domestic wastewater facilities may be covered under SC Regulation 61-9, Sections 503, 504, or 505. When properly managed, waste is applied at a rate that ensures pollutants will be incorporated into the soil or plants and pollutants will not enter streams or groundwater. Land applications sites can be a source of fecal pathogensand stream impairment if not properly managed. Similar to AFO land application sites, land application sites are not allowed to directly discharge to the waterways. Direct discharges from land applications sites to surface waters of the State are illegal and are subject to enforcement actions by SCDHEC.

The Town of Holly Hill's wastewater treatment facility holds permit ND0063380 for land application of treated wastewater to 55 acres in subwatershed 100. An industrial facility manufacturing MDF is permitted (SC0001147) to apply treated wastewater to a two acre site in subwatershed 100 as well (Figure 10). Use of these areas is regulated by the permit to avoid overapplication of wastewater and any resulting ecological harm

Figure 10. Sites of Land Application of Treated Wastewater



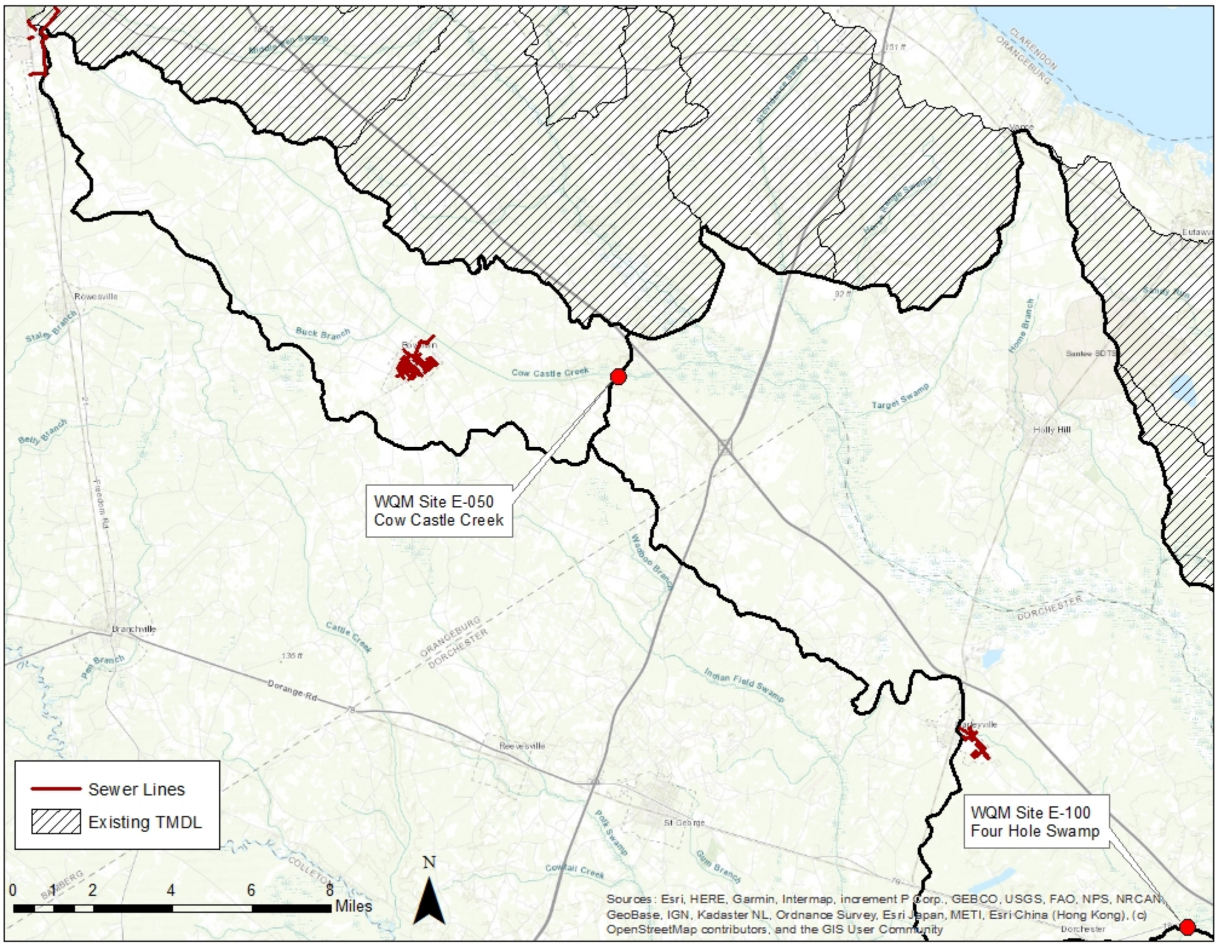
3.2.4 Leaking Sanitary Sewers and Illicit Discharges

Leaking sewer pipes and illicit sewer connections represent a direct threat to public health since they result in discharge of partially treated or untreated human waste to the surrounding environment. Quantifying these sources is highly speculative without direct monitoring of the source since the magnitude is directly proportional to the volume and proximity to the surface water. Typical values of FC bacteria in untreated domestic wastewater range from 10^4 to 10^6 MPN (Most Probable Number)/100mL

(Metcalf and Eddy 1991). According to GIS coverage there are areas of the TMDL drainage area served by a sanitary sewer system so the possibility for leakage exists (Figure 11).

Illicit sewer connections into storm drains result in direct discharge of sewage via the storm drainage system outfalls. Monitoring of storm drain outfalls during dry weather is needed to document the presence or absence of sewage in the drainage systems.

Figure 11. Location of Sewer Lines in the TMDL Watersheds



3.2.5 Failing Septic Systems

Studies demonstrate that groundwater located four feet below properly functioning septic systems contains on average less than one FC bacteria organism per 100 mL (Ayres Associates 1993). Failed or non-conforming septic systems, however, can be a major contributor of *E. coli* and other FC bacteria to the Cow Castle Creek and Lower Four Hole Swamp watershed. Waste from failing septic systems enters surface waters either as direct overland flow or via groundwater. Although loading to streams from failing septic systems is likely to be a continual source, wet weather events can increase the rate of transport of pollutants from failing septic systems because of the wash-off effect from runoff and the increased rate of groundwater recharge.

Based on the 2010 U.S. census, there are an estimated 1,658 households in subwatershed 050, 34% of which are served by a sewer system. In subwatershed 100 there are 4,243 households with only 3% of these located in an area with sewer lines. This indicates that the large majority (88%) of the households within the area covered by this TMDL are using septic tanks and some number of these are likely to be failing and contributing to bacteria in the streams (Table 12).

Table 12. Census Data (2010) and Septic Tank Estimate

Subwatershed	Number of People	Number of Households	Number of Households on Septic Tanks**
050	3644	1658	1089
100	9928	4243	4121
Entire Drainage Area*	13,572	5901	5,210

*Excludes areas with existing TMDLs

**Assumes one septic tank per household not served by municipal WWTP

The available GIS layer for sewer lines in this area includes only large trunk lines and may not include newer sewer lines. For these reasons, the proportion of the watershed served by wastewater treatment plants may be underrepresented and septic tank usage may be overestimated in this document.

3.2.6 Urban and Suburban Runoff

Dogs, cats, and other domesticated pets are the primary source of *E. coli* and other FC bacteria deposited on the urban and suburban landscape. There are also 'urban' wildlife sources: deer, squirrels, raccoons, opossums, pigeons, and other birds, all of which contribute to the bacteria load. Urban runoff is likely negligible within most of the TMDL watershed since there is little development. The exceptions to this are the uppermost area of subwatershed 050 which is adjacent to Orangeburg and the small towns of Holly Hill, Bowman, and Harleyville. There are several major highways in the area as well, including Interstate 26, with varying amounts of development and impervious surfaces around their intersections and interchanges. This area may see growth in the future as communities and industries spread outward from the Charleston area and with the development of the intermodal transportation terminal between Orangeburg and Santee, increasing the potential for urban and suburban runoff.

The City of Orangeburg urbanized area is considered to be a potentially designated MS4 and is currently subject to the LA prescribed for these TMDLs. Like regulated MS4s, potentially designated MS4 entities (as listed in FR 64, 235, p.68837) and any other unregulated MS4 communities located in the Cow Castle Creek and Lower Four Hole Swamp watersheds have the potential to contribute pollutant loadings in stormwater runoff. Future permitted stormwater systems in this watershed will be required to comply with the load reductions prescribed in the WLA and demonstrate consistency with the assumptions and requirements of the TMDL.

4.0 Load-Duration Curve Method

The load-duration curve method was developed as a means of incorporating natural variability, uncertainty, and risk assessment into TMDL development (Bonta and Cleland 2003). The analysis is based on the range of hydrologic conditions for which there are appropriate water quality data. The load-duration curve method uses the cumulative frequency distribution of stream flow and pollutant concentration data to estimate existing and TMDL loads for a water body. Development of the load-duration curve is described in this chapter.

The load-duration curve method depends on an adequate period of record for stream flow data with which to create a flow-duration curve. There is no active flow gauge on Four Hole Swamp. There was a United States Geological Survey (USGS) gauge on Cow Castle Creek near Bowman that was active from 1970 through 1981 and 1995 through 2013. Unfortunately, this period does not correspond to the *E. coli* sampling data used to determine the TMDL for subwatershed 050. Because of the lack of gauges on the streams, it was necessary to choose a different gauge to evaluate flows at the two impaired stations. In this case, USGS 02175500 on the Salkehatchie River near Miley was used. This gauge is located in the same ecoregion as E-050 and E-100 (Mid-Atlantic Floodplains and Low Terraces) and drains the same ecoregions as well (Atlantic Southern Loam Plains and Carolina Flatwoods) (Figure 12). Flow data from 1998 through 2018 were used to construct a flow duration curve for these sites.

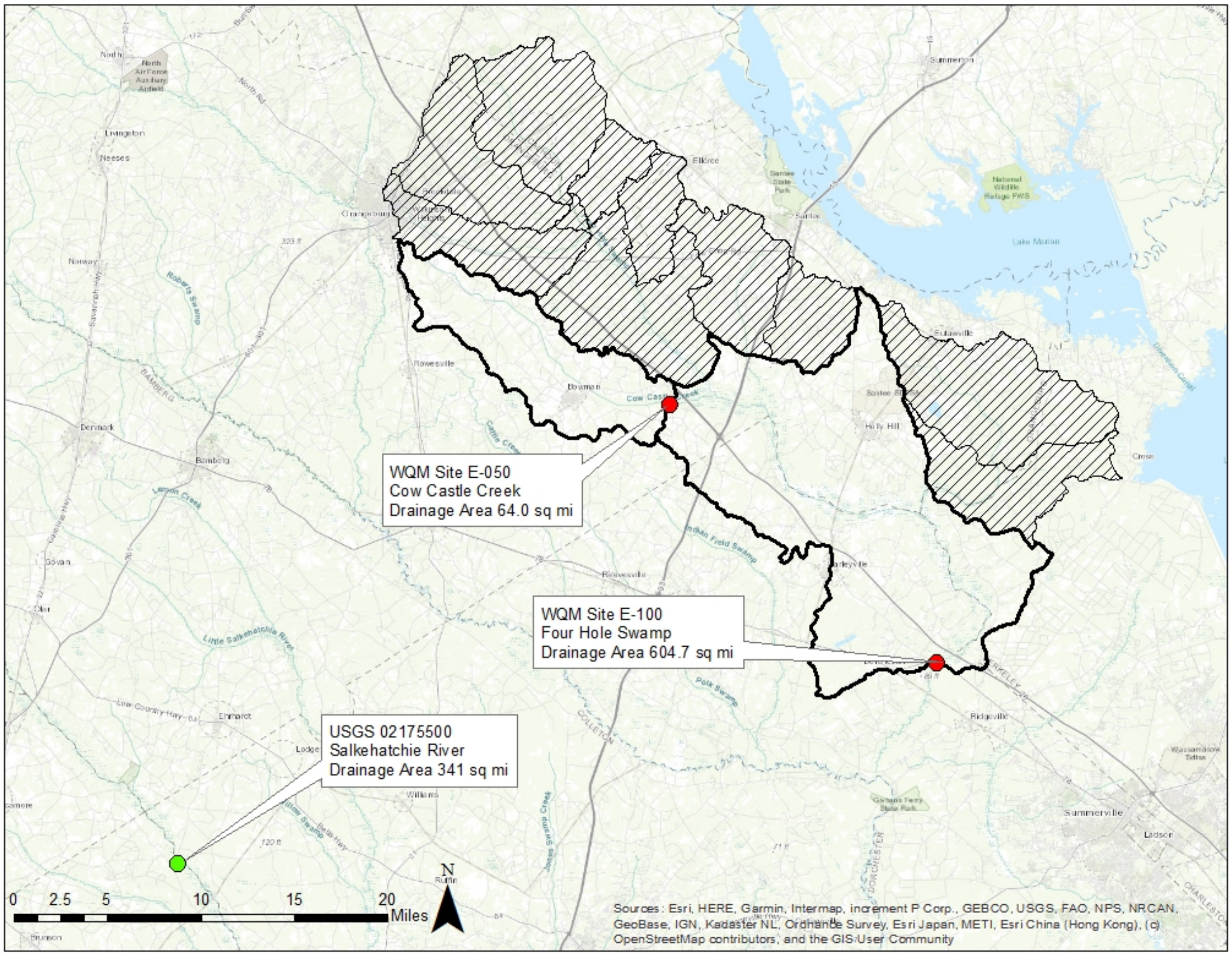
The drainage areas for the WQM stations were delineated using USGS topographic maps and ArcGIS (Figure 1). Flows at the impaired WQM stations were estimated based on the ratio of the WQM station drainage area to the drainage area of the appropriate USGS gauge. For example, 02175550 records flow from 341 square miles. The drainage area for E-100 is 604.7 square miles, or 177% of the drainage area at 02175500. Daily flows at the gauge were multiplied by 1.77 to arrive at an estimated flow at E-100. Table 13 contains a summary of drainage area statistics used to establish flows at the WQM stations and Figure 12 provides an illustration of monitoring and gauge locations.

Table 13. Drainage Area Statistics

Site	Area (square miles)	Ratio Used to Estimate Flow at WQM Sites
USGS Gauge 02175500	341	
E-050	64.0	64.0/341=0.19
E-100	604.7*	604.7/341=1.77

*Area includes existing TMDL watersheds for purpose of estimating flow at WQM station

Figure 12. Location of USGS Gauge Used in Load Duration Analysis

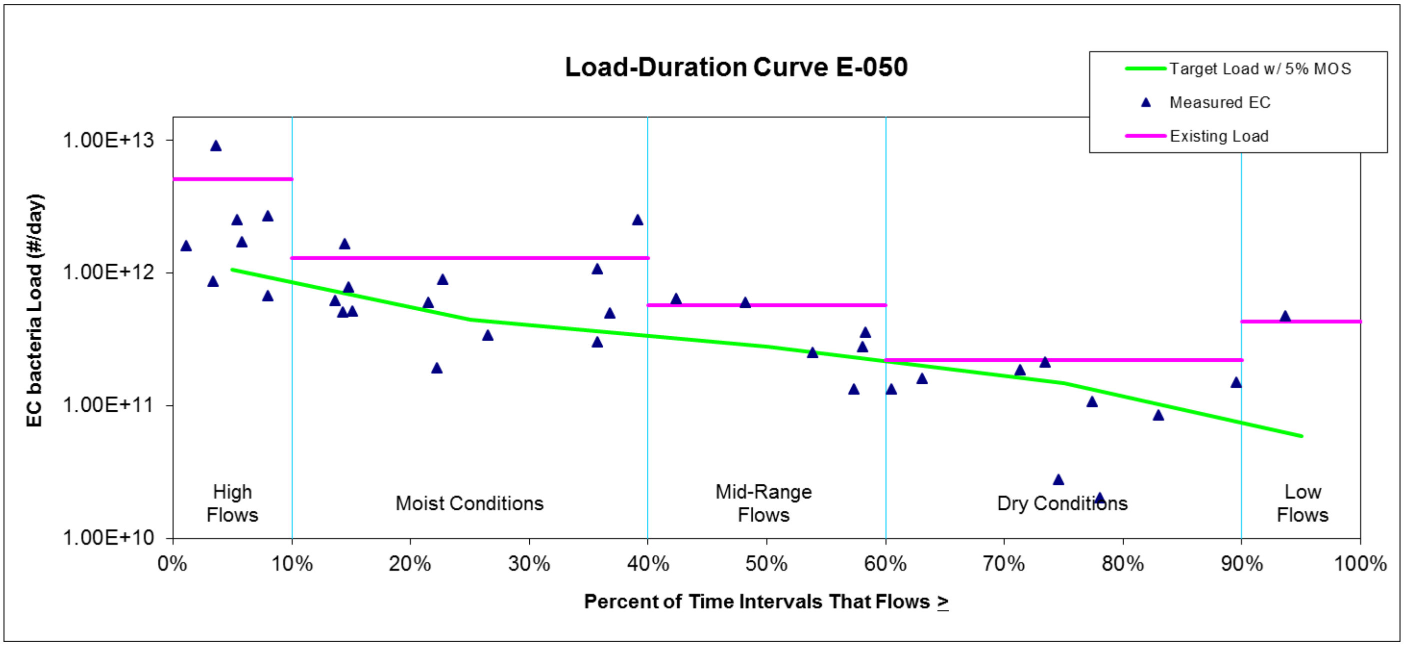


Flow duration curves were created by ranking estimated flows at each WQM site from highest to lowest and calculating the probability of occurrence (presented as a percentage or duration interval), where zero corresponds to the highest flow. The duration interval can be used to determine the percentage of time a given flow is achieved or exceeded, based on the period of record. The flow duration curve was divided into five hydrologic condition categories (High Flows, Moist Conditions, Mid-Range, Dry Conditions and Low Flows). Categorizing flow conditions and plotting sampling data on the same graph can assist in determining which hydrologic condition results in the greatest number of exceedences. A high number of exceedences under dry conditions might indicate a point source or illicit connection issue, whereas exceedences occurring during wet conditions may indicate nonpoint sources. Data within the High Flow and Low Flow categories are generally not used in the development of a TMDL due to their infrequency.

Flow from the Town of Bowman's WWTP sited upstream of E-050 is not sufficient to alter the flow duration curve, and as such, no adjustments were made to account for it. The design flow of the plant is 0.77% of the average adjusted flow in the creek at E-050. The actual long term average facility discharge flow is 0.33% of the stream flow average.

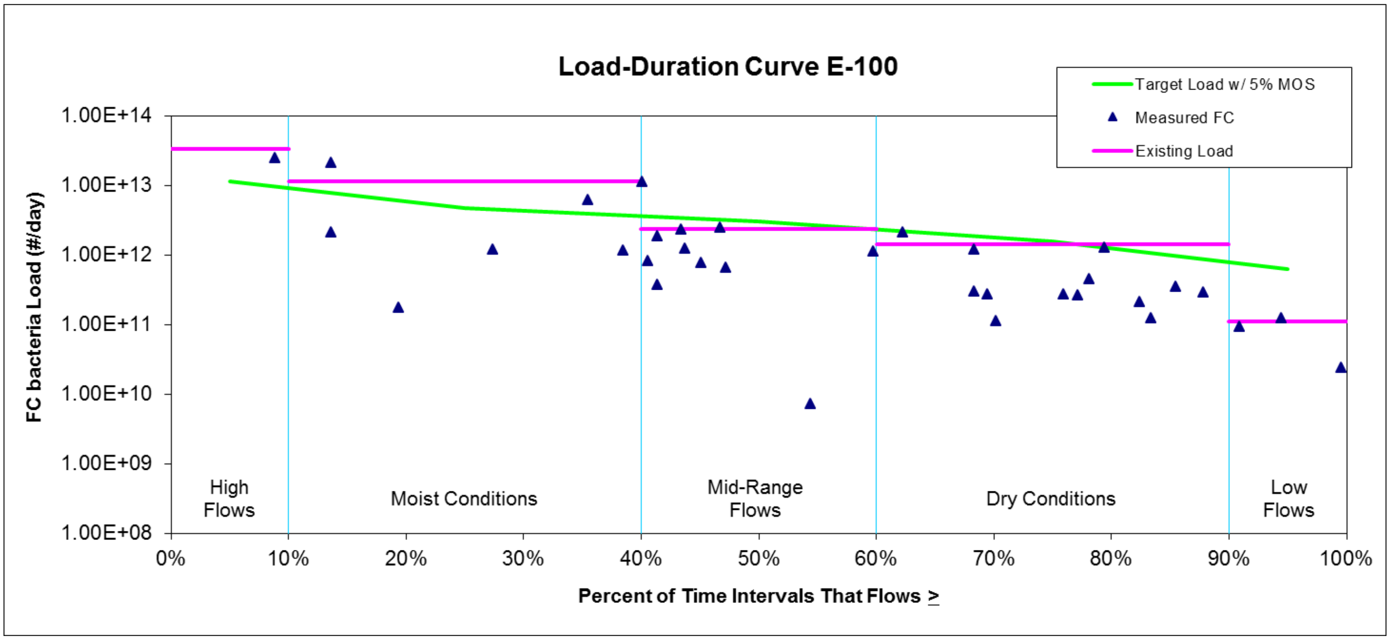
For WQM site E-050, the load-duration curve was created using *E. coli* bacteria data. The allowable load was determined using daily flow and the *E. coli* water quality criterion. The water quality target was set at 332 MPN/100ml which is 5% lower than the instantaneous water quality criterion of 349 MPN/100ml. This allows a 5% explicit margin of safety (MOS) to be reserved from the water quality criterion. The load duration curve for E-050 is presented in Figure 13.

Figure 13. Load Duration Curve E-050



The load duration curve for E-100 was created using FC bacteria data. The water quality target was set to 380cfu/100ml which is 5% lower than the FC bacteria instantaneous criterion of 400cfu/100ml (the criterion in place before the water quality standard was changed to *E. coli*). A 5% explicit MOS was reserved from the water quality criterion. The allowable load of *E. coli* bacteria was then determined using daily flow, the FC bacteria water quality criterion, and a unit conversion factor that converts the FC bacteria load to an *E. coli* load. The unit conversion factor used for FC data was derived from the relationship established between FC bacteria and *E. coli* bacteria in freshwaters determined during SCDHEC's 2009 pathogen indicator study. The load duration curve for E-100 is presented in Figure 14.

Figure 14. Load Duration Curve for E-100



In a load-duration curve, the independent variable (X axis) represents the percentage of time that the estimated flow would be greater than X. In this case flows are represented by categories: high, moist, mid-range, dry, and low. The dependent variable (Y axis) represents the bacteria load (cfu/100ml for FC bacteria and MPN/100ml for *E. coli*) at each flow. For instance, in each of the flow ranges represented on the graph, existing and target loads for E-050 were calculated by the following:

Existing Load (MPN/day) = Mid-Point Flow in Each Hydrologic Category (ft^3/s) x 90th Percentile *E. coli* Concentration x Conversion Factor (24465758.4)

Load Allocation to Meet Target Load (*E. coli* bacteria MPN/day) = Mid-Point Flow in Each Hydrologic Category (ft^3/s) x 332 (*E. coli* Bacteria WQ criterion minus a 5% MOS (MPN/100 ml)) x Conversion Factor (24465758.4)

Percent Reduction = (Existing Load – Load Allocation to meet Target Load) / Existing Load

Instantaneous loads were calculated for each station by converting measured bacteria concentrations into a load, or number of bacteria per day. *E. coli* or FC bacteria samples (MPN or cfu/100ml) were multiplied by the estimated in-stream flow on the day of sampling. This value was then multiplied by a conversion factor to determine loading. Load data were plotted on the load-duration graph based on the flow duration interval for the day of sampling. Samples that lie below the target line (green line) on the load-duration curve are in compliance with the water quality standard (blue triangles in Figures 13 and 14). Only the instantaneous WQS was targeted because there were insufficient data to evaluate against the 30-day geometric mean.

An existing load was determined for each hydrologic category for the TMDL calculations. The 90th percentile of measured bacteria concentrations within each of the hydrologic categories was multiplied by the flow at each category midpoint (i.e., flow at the 25% duration interval for moist conditions, 50% interval for mid-range, and 75% for dry conditions). Existing loads were then plotted on the load-duration curve (pink line in Figures 13 and 14). These values were compared to the target load (which includes an explicit 5% MOS) at each hydrologic category midpoint to determine the percent load reduction necessary to achieve compliance with the WQS. The TMDL assumes that if the highest percent reduction is achieved then the WQS will be attained under all flow conditions.

5.0 Development of the Total Daily Maximum Load

A TMDL for a given pollutant and water body is comprised of the sum of individual waste load allocations (WLAs) for point sources, and load allocations (LAs) for both nonpoint sources and natural background levels. In addition, the TMDL must include a margin of safety (MOS), either implicit or explicit, to account for the uncertainty in the relationship between pollutant loads and the quality of the receiving water body. Conceptually, this definition is represented by the equation:

$$TMDL = \sum WLAs + \sum LAs + MOS$$

The TMDL is the total amount of pollutant that can be assimilated by the receiving water body while still achieving compliance with the WQS. In TMDL development, allowable loadings from all pollutant sources that cumulatively amount to no more than the TMDL must be established and this provides the basis to establish water quality-based controls.

For most pollutants, TMDLs are expressed as a mass load (e.g., kilograms per day). For bacteria, however, TMDLs are expressed in terms of number, colony forming units (cfu), organism counts (or resulting concentration), or MPN, in accordance with 40 CFR 130.2(l).

5.1 Critical Conditions

These TMDLs are based on flow intervals between 10% and 90% and exclude extreme high and low flow conditions. Flows that are characterized as ‘Low’ or ‘High’ were not included in the analysis. The critical condition for each monitoring station is identified as the flow condition requiring the largest percent reduction, within the 10-90% duration intervals. Critical conditions for the WQM stations are listed in Table 14. These data indicate that for both WQM site E-050 and E-100, moist conditions result in the largest bacteria loads and this is the critical condition for both stations.

5.2 Existing Load

An existing load was determined for each hydrologic category for the TMDL calculations as described in Section 4.0 of this TMDL document. The existing load under the critical condition described in Section 5.1 was used in the TMDL calculations. Loadings from all potential sources are included in this value such as cattle, failing septic systems as well as wildlife. The existing loads for both stations are provided in Appendix A.

Table 14. Percent Reduction Necessary to Achieve Target Load by Hydrologic Category

WQM Site	Stream	Moist Conditions	Mid-Range Flow	Dry Conditions
E-050	Cow Castle Creek	66%	51%	34%
E-100	Four Hole Swamp	58%	0%*	1%

*There were no exceedences during this flow condition

Highlighted cells indicate critical conditions.

5.3 Waste Load Allocation

The waste load allocation (WLA) is the portion of the TMDL allocated to NPDES-permitted point sources (USEPA 1991). Note that all illicit dischargers, including SSOs, are illegal and not covered under the WLA of these TMDLs.

5.3.1 Continuous Point Sources

There is one NPDES-permitted municipal wastewater treatment plant and two NPDES-permitted industrial facilities with *E. coli* limits in the TMDL watersheds. The Town of Bowman operates under NPDES permit number SC0040037 which allows a discharge of up to 0.236 million gallons per day (0.365 cfs) into Cow Castle Creek. Holcim Cement and Giant Cement have small sanitary components to their effluent which is discharged to Home Branch and Four Hole Swamp, respectively. To determine the WLA for the Town of Bowman, the design flow was multiplied by the allowed permitted maximum *E. coli* concentration (349 MPN/100ml) and a unit conversion factor (24465758.4). For the cement plants, the long term average flow (a five year average provided by the permitting engineer) for the internal outfall which contains the sanitary effluent was multiplied by 349 MPN/100ml and the conversion factor (Table 15).

Table 15. Wasteload Allocation for Subwatershed 050

Subwatershed	Facility Name	Permit Number	Flow (MGD/cfs)	WLA *E. coli* (MPN/day)
050	Town of Bowman WWTP	SC0040037	0.236 / 0.365*	3.12E+09
100	Holcim Cement	SC0002992	.00436/.00675**	5.76E+07
100	Giant Cement	SC0022667	.00150/.00230**	1.96E+07

* Facility design flow

** Five year average flow

Any future continuous discharges will be required to meet the prescribed loading for *E. coli* based on permitted flow and an allowable permitted maximum concentration of 349MPN/100mL.

5.3.2 Non-continuous Point Sources

Non-continuous point sources include all NPDES-permitted stormwater discharges, including current and future MS4s, construction and industrial stormwater discharges covered under permits numbered SCS000000 & SCR100000 regulated under SC *Water Pollution Control Permits* Regulation 122.26(b)(14) & (15). Illicit discharges, including SSOs, are not covered under any NPDES permit and are subject to enforcement mechanisms. Other non-urbanized areas may be required under the NPDES Phase II Stormwater Regulations to obtain a permit for the discharge of stormwater.

The City of Orangeburg was not automatically designated as a regulated small (Phase II) MS4 and as such it is considered a potentially designated MS4. Potentially designated MS4s may be subject to permitting by SCDHEC if they meet the following criteria (FR 64, No. 235/Wed., Dec. 8, 1999/p. 68735):

- Population density of at least 10,000 and >1000 people/square mile
- They are found to contribute substantially to the pollutant loadings from an existing MS4
- A TMDL defines the need to cover unregulated small MS4s, construction activities, and industrial/commercial sources
- It is determined that discharges from the above sources contribute to violation of water quality standards

As a potentially designated small MS4 entity, the City of Orangeburg urbanized area is subject to the LA for the purposes of this TMDL document until such time that the MS4 becomes regulated and is issued a stormwater permit.

The South Carolina Department of Transportation (SCDOT) is currently the only designated MS4 within the Cow Castle Creek and Lower Four Hole Swamp Watersheds. SCDOT operates under NPDES MS4 Permit SCS040001 and owns and operates roads within the watershed. However, the Department recognizes that SCDOT is not a traditional MS4 in that it does not possess statutory taxing or enforcement powers. SCDOT does not regulate land use or zoning, issue building or development permits.

Waste load allocations for stormwater discharges are expressed as a percentage reduction instead of a numeric loading due to the uncertain nature of stormwater discharge volumes and recurrence intervals. All current and future stormwater discharges are required to meet the percentage reduction or the existing instream standard for the pollutant of concern. The percent reduction is based on the maximum percent reduction (critical condition) within any hydrologic category necessary to achieve target conditions. Table 16 presents the reduction needed for the impaired stations. The reduction percentages in these TMDLs also apply to the FC bacteria or *E. coli* waste load attributable to those areas of the watershed that are covered or will be covered under NPDES MS4 permits.

As appropriate information is made available to further define the pollutant contributions for the permitted MS4, an effort may be made to revise these TMDLs. This effort will be initiated as resources permit and if deemed appropriate by the Department. For the Department to revise these TMDLs the following information should be provided, but not limited to:

1) An inventory of service boundaries of the MS4 covered in the MS4 permit, provided as ARCGIS compatible shape files.

2) An inventory of all existing and planned stormwater discharge points, conveyances, and drainage areas for the discharge points, provided as ArcGIS compatible shape files. If drainage areas are not known, any

information that would help estimate the drainage areas should be provided. The percentage of impervious surface within the MS4 area should also be provided.

3) Appropriate and relevant data should be provided to calculate individual pollutant contributions for the MS4 permitted entities. At a minimum, this information should include precipitation, water quality, and flow data for stormwater discharge points.

Table 16. Percent Reduction Needed to Achieve Target Load for Non-Continuous Point Sources

WQM Site	Stream	% Reduction
E-050	Cow Castle Creek	66%
E-100	Four Hole Swamp	58%

Compliance with terms and conditions of existing and future NPDES sanitary and stormwater permits (including all construction, industrial, and MS4) will effectively implement the WLA and demonstrate consistency with the assumptions and requirements of the TMDL.

5.4 Load Allocation

The Load Allocation applies to the nonpoint sources of *E. coli* and other FC bacteria and is expressed both as a load and as a percent reduction. The load allocation is calculated as the difference between the target load under the critical condition and the point source WLA. The load allocation is listed in Table 17. There may be other unregulated MS4s located in the Cow Castle Creek and Lower Four Hole Swamp Watersheds that are subject to the LA components of these TMDLs. At such time that the referenced entities, or other future unregulated entities become regulated NPDES MS4 entities and are subject to applicable provisions of SC Regulation 61-68D, they will be required to meet load reductions prescribed in the WLA component of the TMDL. This also applies to future discharges associated with industrial and construction activities that will be subject to SC R. 61-9 122.26(b)(14) & (15) (SCDHEC 2011).

5.5 Seasonal Variability

Federal regulations require that TMDLs consider the seasonal variability in watershed loading. The variability in these TMDLs is accounted for by using multi-year hydrological and water quality sampling data sets.

5.6 Margin of Safety

The margin of safety (MOS) may be explicit and/or implicit. The explicit margin of safety is 5% of the TMDL, or in the case of FC TMDLs, 20 cfu/100mL of the instantaneous criterion of 400 cfu/100 mL (380 cfu/100mL); and in the case of *E. coli* TMDLs, 17 MPN/100mL of the instantaneous criterion of 349 MPN/100 mL (332 MPN/100mL). The MOS is expressed as the value calculated from the critical condition defined in Section 5.1 and is the difference between the TMDL and the sum of the WLA and LA.

A 5% MOS in freshwaters impaired for *E. coli* may be calculated as the ratio of *E.coli* MPN/100 mL to FC bacteria cfu/100 mL or 20*0.8725 = 17 MPN/100 mL of the instantaneous *E. coli* criterion of 349 MPN/100 mL (332 MPN/100 mL). This conversion is deemed appropriate by the Department and was derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters determined during the 2009 Pathogen Indicator Study.

5.7 TMDL

For most pollutants, TMDLs are expressed as a mass load (e.g., kilograms per day). For bacteria, however, TMDLs are expressed in terms of cfu or MPN or organism counts, in accordance with 40 CFR 130.2(l). Only the instantaneous water quality criterion was targeted for the Cow Castle Creek and Lower Four Hole Swamp Watersheds because there is insufficient data to evaluate against the 30-day geometric mean. The target load is defined as the load (from point and nonpoint sources) minus the MOS that a stream station can receive while meeting the WQS. The TMDL value is the median target load within the critical condition (i.e., the middle value within the hydrologic category that requires the greatest load reduction) plus the WLA and MOS.

While TMDL development was based on instantaneous water quality criterion, terms and conditions of NPDES permits for continuous discharges require facilities to demonstrate compliance with both geometric mean and instantaneous water quality criteria for FC bacteria in treated effluent. NPDES permits for continuous dischargers require data collection sufficient to monitor for compliance of both criteria at the point of outfall.

Table 17 indicates the percentage reduction or water quality standard required for both subwatersheds analyzed in this TMDL document. Note that all future regulated NPDES-permitted stormwater discharges will also be required to meet the prescribed percentage reductions, or the water quality standard. It should be noted that in order to meet the WQS for *E. coli* bacteria prescribed load reductions must be targeted from all sources, including NPDES permitted and nonpoint sources.

Based on the available information at this time, the portions of the subwatersheds that drain directly to regulated MS4s and those that drain through unregulated MS4s have not been clearly defined within the MS4 jurisdictional area. Loading from both types of sources (regulated and unregulated) typically occurs in response to rainfall events, and discharge volumes as well as recurrence intervals are largely unknown. Therefore, where applicable, the regulated MS4 is assigned the same percent reduction as the non-regulated sources in the watershed. Compliance with the MS4 permit in regard to this TMDL document is determined at the point of discharge to waters of the state. The regulated MS4 entity is only responsible for implementing the TMDL WLA in accordance with their MS4 permit requirements and is not responsible for reducing loads prescribed as LA in this TMDL document.

Table 17. Total Maximum Daily Loads for Cow Castle Creek, Lower Four Hole Swamp and Tributaries

	Existing Load		TMDL		Margin of Safety		Waste Load Allocation (WLA)			Load Allocation (LA)		
Station	**Existing FC Load (cfu/day)**	**Existing *E. Coli* Load (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**Continuous Source *E. coli*[1] (MPN/day)**	**Non-Continuous Sources[2,3] (% Reduction)**	**Non-Continuous SCDOT[3,4] (% Reduction)**	**FC Bacteria (cfu/day)**	***E. coli* (MPN/day)**	**% Reduction to Meet LA[3]**
E-050	---	5.67E+11	---	2.96E+11	---	1.44E+10	3.12E+09 (see note 1)	66%	66%	---	2.79E+11	66%
E-100	1.14E+13	9.98E+12 (see note 5)	5.08E+12	4.44E+12 (see note 5)	2.54E+11	2.16E+11 (see note 5)	7.73E+07 (see note 1)	58%	58%	4.83E+12	4.22E+12 (see note 5)	58%

1. WLAs are expressed as a daily maximum. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern. Future loadings will be developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100ml.
2. Percent reduction applies to all NPDES-permitted stormwater discharges, including current and future MS4, construction and industrial discharges covered under permits numbered SCS & SCR. Stormwater discharges are expressed as a percentage reduction due to the uncertain nature of stormwater discharge volumes and recurrence intervals. Stormwater discharges are required to meet percentage reduction or the existing instream standard for pollutant of concern in accordance with their NPDES Permit.
3. Percent reduction applies to existing instream *E. coli.*
4. By implementing the best management practices that are prescribed in either the SCDOT annual SWMP or the SCDOT MS4 permit to address fecal coliform bacteria or *E. coli*, SCDOT will comply with these TMDLs and their applicable WLAs to the maximum extent practicable (MEP) as required by its MS4 permit.
5. Expressed as E. coli (MPN/day). Loadings are developed by applying a conversion factor to values calculated for FC bacteria. This conversion factor is derived from an established relationship between FC bacteria and *E. coli* WQS in freshwaters.

5.8 Reasonable Assurance

NPDES permits are issued for regulated dischargers, including continuous and non-continuous sources of pathogenic bacteria. In freshwaters, the applicable recreational use water quality standard is *E. coli* bacteria. Continuous discharges are required to target the *E. coli* water quality standard at the point of discharge. For regulated non-continuous discharges, the *E. coli* standard should be targeted to the maximum extent practicable. There may be other regulated activities present that could contribute to *E. coli* loadings in the watershed. New septic tanks, animal feeding operations (AFOs), land application of treated sludge or wastewater also require permits that reduce the potential for runoff of bacteria into waters of the State.

Unregulated sources of *E. coli* loadings in the watershed may include wildlife, improper agricultural or silvicultural activities, urban, and suburban runoff. These sources may be reduced through means such as best management practices, local ordinances, and outreach education efforts, as well as 319 grant funded opportunities. SCDHEC has fostered effective partnerships between other federal, state and local entities to help reduce the potential for runoff of bacteria into waters of the State. Once implemented, all these reduction mechanisms will provide reasonable assurance that the recreational use water quality standard will be attained in this watershed.

6.0 Implementation

Implementation of both point (WLA) and non-point (LA) source components of the TMDL are necessary to bring about the required reductions in *E. coli* bacteria loading to the Cow Castle Creek and Lower Four Hole Swamp Watersheds. Using existing authorities and mechanisms, implementation guidance providing information on how point and non-point sources of pollution may be abated to meet water quality standards is provided. Sections 6.1.1-6.1.7 presented below correspond with sections 3.1.1-3.2.6 of the source assessment presented in the TMDL document. As the implementation strategy progresses, SCDHEC will continue to monitor the effectiveness of implementation measures and evaluate water quality where deemed appropriate.

Point sources are discernible, confined, and discrete conveyances of pollutants to a water body including but not limited to pipes, outfalls, channels, tunnels, conduits, man-made ditches, etc. The Clean Water Act's primary point source control program is the National Pollutant Discharge Elimination System (NPDES). Point sources can be broken down into continuous and non-continuous point sources. Some examples of a continuous point source are wastewater treatment facilities (WWTF) and industrial facilities. Some examples of non-continuous point sources include MS4s and construction activities. Current and future NPDES discharges in the referenced watershed are required to comply with the load reductions prescribed in the waste load allocation (WLA).

Nonpoint source pollution originates from multiple sources over a relatively large area. It is diffuse in nature and indistinct from other sources of pollution. It is generally caused by the pickup and transport of pollutants from rainfall moving over and through the ground. Nonpoint sources of pollution may include, but are not limited to wildlife, agricultural activities, illicit discharges, failing septic systems, and urban runoff. Nonpoint sources located in unregulated portions of subwatersheds 050 and 100 are subject to the load allocation (LA) and not the WLA of the TMDL document.

South Carolina has several tools available for implementing the non-point source components of these TMDLs. The *Implementation Plan for Achieving Total Maximum Daily Load Reductions from Nonpoint Sources for the State of South Carolina* (SCDHEC 1998) document is one example. Another key component for interested parties to control pollution and prevent water quality degradation in the TMDL watersheds would be the establishment and administration of a program of Best Management Practices (BMPs). Best management practices may be defined as a practice or a combination of practices that have been determined to be the most effective, practical means used in the prevention and/or reduction of pollution.

Interested parties (local stakeholder groups, universities, local governments, etc.) may be eligible to apply for CWA §319 grants to install BMPs that will implement the LA portions of these TMDLs and reduce nonpoint source *E. coli* loading to the TMDL watersheds. Congress amended the Clean Water Act (CWA) in 1987 to establish the Section 319 Nonpoint Source Management Program. Under Section 319, States receive grant money to support a wide variety of activities including the restoration of impaired waters. TMDL implementation projects are given highest priority for 319 funding. SCDHEC will also work with existing agencies in the area to provide nonpoint source education in the Cow Castle Creek and Lower Four Hole Swamp watersheds.

The Department recognizes that adaptive management/implementation of these TMDLs might be necessary to achieve the water quality standard and we are committed to targeting the load reductions needed to improve water quality in the Cow Castle Creek and Lower Four Hole Swamp watersheds. As additional data and/or information become available, it may become necessary to revise and/or modify the TMDL target accordingly.

6.1 Implementation Strategies

The strategies presented in this document for implementation of the Cow Castle Creek, Lower Four Hole Swamp and Tributaries Watershed TMDL are not inclusive and are to be used only as guidance. The strategies are informational suggestions that may lead to the required load reductions being met while demonstrating consistency with the assumptions and requirements of the TMDL. Application of certain strategies provided may be voluntary and are not a substitute for actual NPDES permit conditions.

6.1.1 Continuous Point Sources

Continuous point source WLA reductions are implemented through NPDES permitting. Existing and future continuous discharges are required to meet the prescribed loading for the pollutant of concern and demonstrate consistency with the assumptions and requirements of the TMDL. *E. coli* loadings are developed based upon permitted flow and an allowable permitted maximum *E. coli* concentration of 349 MPN/100mL.

6.1.2 Non-continuous Point Sources

An iterative BMP approach as defined in the general stormwater NPDES MS4 permit is expected to provide significant implementation of the WLA. Permit requirements for implementing WLAs in approved TMDLs will vary across waterbodies, discharges, and pollutant(s) of concern. The allocations within a TMDL can take many different forms – narrative, numeric, specific BMPs – and may be complimented by other special requirements such as monitoring.

The level of monitoring necessary, deployment of structural and non-structural BMPs, evaluation of BMP performance, and optimization or revisions to the existing pollutant reduction goals of the Storm Water Management Plan (SWMP) or any other plan is TMDL and watershed specific. Hence, it is expected that NPDES permit holders will evaluate their existing SWMP or other plans in a manner that would effectively address implementation of these TMDLs with an acceptable schedule and activities for their permit compliance. The Department (permit writers, TMDL project managers, and compliance staff) is willing to assist in developing or updating the referenced plan as deemed necessary. Please see Appendix B for additional information on evaluating the effectiveness of an MS4 Permit as it relates to compliance with approved TMDLs. For SCDOT, existing, and future NPDES MS4 permittees, compliance with terms and conditions of the NPDES permit is effective implementation of the WLA to the Maximum Extent Practicable (MEP) and demonstrates consistency with the assumptions and requirements of the TMDL. For existing and future NPDES construction and industrial stormwater permittees, compliance with terms and conditions of the permit is effective implementation of the WLA. Required load reductions in the LA portion of this TMDL can be implemented through voluntary measures and are eligible for CWA §319 grants.

The Department acknowledges that progress with the assumptions and requirements of the TMDL by MS4s is expected to take one or more permit iteration. Achieving the WLA reduction for the TMDL may constitute MS4 compliance with its SWMP, provided the MEP definition is met, even where the numeric percent reduction may not be achieved in the interim.

Regulated MS4 entities are required to develop a SWMP that includes the following: public education, public involvement, illicit discharge detection & elimination, construction site runoff control, post construction runoff control, and pollution prevention/good housekeeping. These measures are not exhaustive and may include additional criteria depending on the type of NPDES MS4 permit in question. The following examples are recognized as acceptable stormwater practices and may be applied to unregulated MS4 entities or other interested parties in the development of a stormwater management plan.

An informed and knowledgeable community is crucial to the success of a stormwater management plan (USEPA, 2005). MS4 entities may implement a public education program to distribute educational materials to the community or conduct equivalent outreach activities about the impacts of stormwater discharges on local waterbodies and the steps that can be taken to reduce stormwater pollution. Some appropriate BMPs may be brochures, educational programs, storm drain stenciling, stormwater hotlines, tributary signage, and alternative information sources such as websites, bumper stickers, etc. (USEPA, 2005).

The public can provide valuable input and assistance to a stormwater management program and they may have the potential to play an active role in both the development and implementation of the stormwater program where deemed appropriate by the entity. There are a variety of practices that can involve public participation such as public meetings/citizens panels, volunteer water quality monitoring, volunteer educators, community clean-ups, citizen watch groups, and "Adopt a Storm Drain" programs which encourage individuals or groups to keep storm drains free of debris and monitor what is entering local waterways through storm drains (USEPA, 2005).

Illicit discharge detection and elimination efforts are also necessary. Discharges from MS4s often include wastes and wastewater from non-stormwater sources. This enters the system through either direct connections or indirect connections. The result is untreated discharges that contribute high levels of pollutants, including heavy metals, toxics, oil and grease, solvents, nutrients, viruses, and bacteria to receiving waterbodies (USEPA, 2005). Pollutant levels from these illicit discharges have been shown in EPA studies to be high enough to significantly degrade receiving water quality and threaten aquatic, wildlife, and human health. MS4 entities may have a storm sewer system map which shows the location of all outfalls and to which waters they discharge. If not already in place, an ordinance prohibiting non-stormwater discharges into a MS4 with appropriate enforcement procedures may be developed. Entities may also have a plan for detecting and addressing non-stormwater discharges. The plan may include locating problem areas through infrared photography, finding the sources through dye testing, removal/correction of illicit connections, and documenting the actions taken to illustrate that progress is being made to eliminate illicit connections and discharges.

A program might also be developed to reduce pollutants in stormwater runoff to the MS4 area from construction activities. An ordinance or other regulatory mechanism may exist requiring the implementation of proper erosion and sediment controls on applicable construction sites. Site plans should be reviewed for projects that consider potential water quality impacts. It is recommended that site inspections should be conducted, and control measures enforced where applicable. A procedure might also exist for considering information submitted by the public (USEPA, 2005). For information on specific BMPs please refer to the SCDHEC Stormwater Management BMP Handbook online at: https://scdhec.gov/environment/water-quality/stormwater/bmp-handbook

Post-construction stormwater management in areas undergoing new development or redevelopment is recommended because runoff from these areas has been shown to significantly affect receiving waterbodies. Many studies indicate that prior planning and design for the minimization of pollutants in post-construction stormwater discharges is the most cost-effective approach to stormwater quality management (USEPA, 2005). Strategies might be developed to include a combination of structural and/or non-structural BMPs. An ordinance or other regulatory mechanism may also exist requiring the implementation of post-construction runoff controls and ensuring their long term-operation and maintenance. Examples of non-structural BMPs are planning procedures and site-based BMPs (minimization of imperviousness and maximization of open space). Structural BMPs may include but are not limited to stormwater retention/detention BMPs, infiltration BMPs (dry wells, porous pavement, etc.), and vegetative BMPs (grassy swales, filter strips, rain gardens, artificial wetlands, etc.).

Pollution prevention is also a key element of stormwater management programs. This requires the MS4 entity to examine and alter their programs or activities to ensure reductions in pollution are occurring. A plan should be developed to prevent or reduce pollutant runoff from municipal operations into the storm sewer system and employees trained on ways to incorporate and document pollution prevention/good housekeeping techniques. The MS4 operator can use training materials that are available from EPA or relevant organizations (USEPA, 2005).

6.1.3 Wildlife

Methods for managing the bacteria contribution from wildlife will vary from location to location. In developed areas it may make sense to divert wildlife from sensitive areas by fencing, mowing, landscaping changes, and trimming trees to reduce bird roosting. Food sources for wildlife can be kept to a minimum by prohibiting feeding by the public, by removing trash, pet food, and palatable plant species. In rural, undeveloped areas, which includes much of the watershed evaluated for this TMDL document, these methods would not be practical.

Although there are many ways to discourage birds and other wildlife from waterways by removing attractants or harassing nuisance species, any plans to do so should be undertaken only with a good understanding of the animal populations in question. Federal and state permits may be required to interfere with wildlife, and some nuisance species such as Canada geese and other migratory birds are protected by federal law. It is recommended that the South Carolina Department of Natural Resources, USDA-APHIS, and the United States Fish and Wildlife Service be consulted prior to interfering with wildlife (USEPA, 2001).

6.1.4 Agricultural Activities

Suggested forms of implementation for agricultural activities will vary depending on location. Agricultural BMPs can be vegetative, structural, or management oriented. When selecting BMPs, it is important to keep in mind that nonpoint source pollution occurs when a pollutant becomes available, is detached, and then transported to nearby receiving waters. For BMPs to be effective, the transport mechanism of the pollutant, in this case *E. coli* bacteria, needs to be identified.

For livestock in the watershed, installing fencing along the streams within the watershed and providing an alternative water source where livestock are present would eliminate direct contact with the streams. When grazing animals have access to streams, they have a large impact on bacteria loads even if few in number. If fencing is not feasible, it has been shown that installing water troughs within a pasture area reduced the amount of time livestock spent drinking directly from streams by 92% (Sheffield et al.,1997). In addition to reducing bacteria in the stream, this BPM resulted in a 77% reduction in stream bank erosion.

Most of the agricultural activities observed in the Cow Castle Creek and Lower Four Hole Swamp Watersheds consisted of row crops, sod farming, hay fields and silviculture. For row crops, many practices exist to reduce nonpoint source pollution. Unstabilized soil directly adjacent to surface waters can contribute to bacteria loading during periods of runoff after rain events. Agricultural field borders and filter strips (vegetative buffers) can provide erosion control around fields. These borders may be harvested as hay and provide an area in which farmers can turn equipment around when working the field (SCDNR, 1997). A study conducted in 1998 by the American Society of Agricultural and Biological Engineers (ASABE 1998) demonstrated that a vegetative buffer measuring 6.1 meters in width can reduce fecal bacteria runoff concentrations to a non-detectable amount. A buffer of this width was also shown to reduce phosphorous and nitrogen concentrations in runoff by 75%.

The agricultural BMPs listed above are just a sample of the many accepted practices that are currently available. Many other techniques such as conservation tillage, responsible pest management, and precision agriculture also exist and may contribute to an improvement in overall water quality in the TMDL watersheds. Education should be provided to local farmers on these methods as well as acceptable manure spreading and holding practices. South Carolina-specific information on agriculture BMPs is available from the Clemson Cooperative Extension Service. http://www.clemson.edu/extension/water

The Natural Resources Conservation Service (NRCS, a division of USDA) provides financial and technical assistance to help landowners address natural resource concerns, promote environmental quality, and protect wildlife habitat on property they own or control. Their website contains a wealth of information on agriculture BMPs and water quality issues associated with agricultural practices. Cost-share funds are available through the NRCS's Environmental Quality Incentives Program (EQIP). EQIP helps farmers improve production while protecting environmental quality by addressing such concerns as soil erosion and productivity, grazing management, water quality, animal waste, and forestry concerns. More information about conservation and funding sources may be found at: https://www.farmers.gov/ and https://www.nrcs.usda.gov/wps/portal/nrcs/main/national/programs/financial/eqip/ .

6.1.5 Leaking Sanitary Sewers

Leaking sanitary sewers and illicit discharges, although illegal and subject to enforcement, may be occurring the Cow Castle Creek and Lower Four Hole Swamp Watershed. Due to the high concentration of pollutant loading that is generally associated with these discharges, their detection may provide a substantial improvement in overall water quality in the watershed. Detection methods may include, but are not limited to: dye testing, air pressure testing, static pressure testing, and infrared photography. SCDHEC recognizes illicit discharge detection and elimination activities are conducted by regulated MS4 entities pursuant to compliance with existing MS4 permits. Note that these activities are designed to detect and eliminate illicit discharges that may contain FC bacteria or *E. coli*. It is the intent of SCDHEC to work with the MS4 entities to recognize FC bacteria or *E. coli* load reductions as they are achieved. SCDHEC acknowledges that these efforts to reduce illicit discharges and SSOs are ongoing and some reduction may already be accountable (i.e., load reductions occurring during TMDL development process). Thus, the implementation process is an iterative and adaptive process. Regular communication between all implementation stakeholders will result in successful remediation of controllable sources over time. As designated uses are restored, SCDHEC will recognize efforts of implementers where their efforts can be directly linked to restoration.

6.1.6 Failing Septic Systems

A septic system, also known as an onsite wastewater system, is defined as failing when it is not treating or disposing of sewage in an effective manner. The most common reason for failure is improper maintenance by homeowners. Untreated sewage not only contains disease-causing bacteria and viruses, but also unhealthy amounts of nitrate and other chemicals. Failed septic systems can allow untreated sewage to seep into and pollute wells, groundwater, and surface water bodies. Pumping a septic tank is probably the single most important thing that can be done to protect the system. Information on how a septic tank works and proper maintenance is available here: https://scdhec.gov/environment/your-home/septic-tanks and tips on proper usage here: https://www.epa.gov/septic/dos-and-donts-homeowners-brochure

6.1.7 Urban and Suburban Runoff

Urban runoff is surface runoff of rainwater created by urbanization outside of regulated areas. Pavement, compacted areas, roofs, reduced tree canopy and open space increase runoff volumes that rapidly flow into receiving waters. The increase in volume and velocity of runoff may cause stream bank erosion, channel incision and sediment deposition in stream channels. In addition, runoff from these developed areas can increase stream temperatures. This, along with the increase in flow rate and pollutant loads negatively affect water quality and aquatic life (USEPA 2005). Runoff can pick up bacteria along the way. Many strategies currently exist to reduce bacteria loading from urban runoff and the USEPA nonpoint source pollution website provides extensive resources on this subject:

https://www.epa.gov/nps/nonpoint-source-urban-areas

Some examples of urban nonpoint source BMPs are street sweeping, stormwater wetlands, pet waste receptacles (equipped with waste bags), and educational signs which can be installed adjacent to receiving waters in the watershed such as parks, common areas, apartment complexes, trails, etc. Low impact development (LID) may also be effective. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treats stormwater as a resource rather than a waste product. There are many practices that have been used to adhere to these principles such as bioretention facilities, rain gardens, vegetated rooftops, rain barrels, and permeable pavements (USEPA, 2009).

Education should be provided to individual homeowners in the referenced watershed on the contributions to bacteria loading from pet waste. Education to homeowners in the watershed on the fate of substances poured into storm drain inlets should also be provided. For additional information on urban runoff please see the SCDHEC nonpoint source program web page:

https://www.scdhec.gov/environment/your-water-coast/watersheds-program/section-319-nonpoint-source-program

7.0 Resources for Pollution Management

- Citizen's Guide to Protecting Our Water Resources from Runoff Pollution

  https://scdhec.gov/sites/default/files/media/document/CR-002358.pdf

- Polluted Runoff: Nonpoint Source (NPS) Pollution – EPA's landing page for all things NPS

  https://www.epa.gov/nps

- National Menu of Best Management Practices (BMPs) for Stormwater – Based on the six minimum control measures for Phase I and Phase II MS4s

  https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu

- South Carolina Forestry Commission Best Management Practices – Includes streamside management, stream crossings, and managing drainage to protect water quality

  https://www.state.sc.us/forest/refbmp.htm#contents

- Clemson Public Service and Agriculture – Center for Watershed Excellence offers professional training for managing stormwater ponds, assessing BMPs, and landscape managing to protect waterways

  https://www.clemson.edu/public/water/watershed/

- SCDOT Stormwater Management

  https://www.scdot.org/business/storm-water.aspx

- Agricultural Waste Management Field Handbook

  https://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/?&cid=stelprdb1045935

- Manure Management for Small Farms

  https://lpelc.org/manure-management-on-small-farms/

- Managing Canada Geese in Urban Environments

  https://ecommons.cornell.edu/handle/1813/66

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Appendix A: Data Tables for E-050 and E-100

Data WQM Station E-050

E-050 E. coli Counts (exceedences highlighted)

Date	MPN/100ml
2/6/2013	260.3
4/2/2013	633.05
6/4/2013	2419.6
8/7/2013	133.6
10/9/2013	462.2
12/3/2013	410.6
1/15/2014	275.5
3/4/2014	261.3
5/13/2014	201.4
7/7/2014	261.3
9/4/2014	613.1
11/4/2014	378.4
1/6/2015	272.3
3/3/2015	218.7
5/12/2015	394.5
7/13/2015	50.4
9/8/2015	61.3
11/17/2015	261.3
2/9/2016	260.3
4/13/2016	290.9
6/2/2016	2419.6
8/16/2016	185
12/13/2016	579.4
1/10/2017	816.4
2/8/2017	1046.2
3/16/2017	920.8
4/12/2017	328.2
5/17/2017	517.2
6/21/2017	648.8
7/19/2017	435.2
8/30/2017	261.3
9/26/2017	325.5
10/24/2017	2419.6
11/16/2017	980.4
12/5/2017	686.7
1/24/2018	461.1

90th Percentile *E. coli* Concentration (MPN/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
E-050	1596	968	668	492	2420	36

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-050	130.6	55.0	34.7	18.2	7.26

Existing Load (number *E. coli*/day) at each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-050	5.10E+12	1.30E+12	5.67E+11	2.19E+11	4.30E+11

TMDL (number *E. coli* bacteria/day) at Each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-050	1.12E+12	4.70E+11	2.96E+11	1.55E+11	6.20E+10

Load Reduction Necessary (number *E. coli* bacteria/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-050	NA	8.30E+11	2.71E+11	6.40E+10	NA

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-050	NA	66%	51%	34%	NA

Data WQM Station E-100

E-100 Fecal Coliform Bacteria Counts (exceedences highlighted)

Date	cfu/100ml
1/26/2000	1200
2/3/2000	120
2/23/2000	120
3/9/2000	40
4/19/2000	88
5/11/2000	44
6/20/2000	72
7/20/2000	40
8/17/2000	130
9/7/2000	360
10/25/2000	120
11/21/2000	600
12/6/2000	300
1/16/2001	100
2/26/2001	12
4/30/2001	240
6/5/2001	24
7/16/2001	180
8/13/2001	68
9/6/2001	260
10/3/2001	120
11/6/2001	68
12/6/2001	360
1/3/2006	1100
2/22/2006	200
3/30/2006	140
4/5/2006	1
6/27/2006	60
7/6/2006	42
8/2/2006	56
9/6/2006	1200
10/19/2006	67
11/20/2006	88
12/5/2006	80

90th Percentile FC Bacteria Concentration (cfu/100ml) by Hydrologic Category

WQM Site	High Flow 0-10%	Moist Cond. 10-40%	Midrange 40-60%	Dry Cond. 60-90%	Low Flow 90-100%	Number of Samples
E-100	1100	900	300	336	66	34

Flow (cfs) at Midpoint of Each Hydrologic Category

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-100	1234.2	519.6	328.1	172.0	68.6

Existing Load (number FC bacteria/day) at Each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-100	3.32E+13	1.14E+13	2.41E+12	1.41E+12	1.11E+11

TMDL (number FC bacteria/day) at Each Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-100	1.21E+13	5.08E+12	3.21E+12	1.68E+12	6.72E+11

Load Reduction Necessary (number FC bacteria/day) at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-100	NA	6.32E+12	NA*	NA*	NA

*no exceedences occurred during these flow categories so no reductions necessary

Percent Reduction Necessary at Midpoint of Each Hydrologic Category Flow

WQM Site	High Flow (5%)	Moist Cond. (25%)	Midrange (50%)	Dry (75%)	Low Flow (95%)
E-030	NA	58%	NA*	NA*	NA

*no exceedences occurred during these flow categories so no reductions necessary

Appendix B: Evaluating the Progress of MS4 Programs

Described below are approaches that may be used by MS4 permit holders and others implementing TMDLs. These are recommendations and examples only. SCDHEC-BOW recognizes that other approaches may be utilized or employed to meet compliance goals.

1. Calculate pollutant load reduction for each best management practice (BMP) deployed:
    - Retrofitting stormwater outlets
    - Creation of green space
    - LID activities (e.g., creation of porous pavements)
    - Creations of riparian buffers
    - Stream bank restoration
    - Scoop the poop program (how many pounds of poop were scooped/collected)
    - Street sweeping program (amount of materials collected etc.)
    - Construction & post-construction site runoff controls
2. Description & documentation of programs directed towards reducing pollutant loading:
    - Document tangible efforts made to reduce impacts to urban runoff
    - Track type and number of structural BMPs installed
    - Parking lot maintenance program for pollutant load reduction
    - Identification and elimination of illicit discharges
    - Zoning changes and ordinances designed to reduce pollutant loading
    - Modeling of activities & programs for reducing pollutant reductions
3. Description & documentation of social indicators, outreach, and education programs:
    - Number/Type of training & education activities conducted and survey results
    - Activities conducted to increase awareness and knowledge – residents, business owners. What changes have been made based on these efforts? Any measured behavior or knowledge changes?
    - Participation in stream and/or lake clean-up events or activities
    - Number of environmental action pledges
4. Water quality monitoring: A direct and effective way to evaluate the effectiveness of stormwater management plan activities:
    - Use of data collected from existing monitoring activities (e.g., SCDHEC data for ambient monitoring program available through STORET; water supply intake testing; voluntary watershed group's monitoring, etc)
    - Establish a monitoring program for permitted outfalls and/or waterbodies within MS4 areas as deemed necessary– use a certified lab
    - Monitoring should focus on water quality parameters and locations that would both link pollutant sources and BMPs being implemented

Useful Links:

Evaluating the Effectiveness of Municipal Stormwater Programs.

https://www3.epa.gov/npdes/pubs/region3_factsheet_swmp.pdf

The International Stormwater Best Management Practices Database Project

http://www.bmpdatabase.org/

National Water Quality Monitoring Council - Water Quality Data

https://www.waterqualitydata.us/portal/

Spreadsheet Tool for Estimating Pollutant Loads (STEPL)

https://www.epa.gov/nps/spreadsheet-tool-estimating-pollutant-loads-stepl

Measurable Goals Guidance for Phase II Small MS4s

https://www3.epa.gov/npdes/pubs/measurablegoals.pdf

National Menu of BMPs for Stormwater

https://www.epa.gov/npdes/national-menu-best-management-practices-bmps-stormwater#edu

SCDHEC – BOW: The 319 grant program (https://www.s cdhec.gov/environment/your-water-coast/watersheds-program/watersheds-program-contacts) can provide guidance on estimating load reductions for the following BMPs:

- Septic tank repair or replacement
- Removing livestock from streams
- Livestock fencing
- Waste Storage Facilities
- Strip cropping
- Prescribed grazing
- Critical Area Planting
- Runoff Management System
- Waste Management System
- Solids Separation Basin
- Riparian Buffers

Appendix C: Source Assessment Pictures

Figure 15. Stream characteristics in the Cow Castle Creek and Four Hole Swamp Watershed

This area of the state is characterized by low slope, low stream velocities, and at times, very low flow. Flood plains are wide, often wooded, and sometimes inundated for long periods of time. Larger streams and rivers such as Cow Castle Creek near E-050 and Four Hole Swamp have multiple braided channels. At left is Four Hole Swamp at a historical sampling site (E-112). Below left is Cow Castle Creek at E-050 and below right Little Walnut Branch at Taylor Pond Road.

Figure 16. Agriculture and Land Application of Manure, Sludge, and Treated Effluent

Animal agriculture plays a large role in the economy of this area. There are many animal feeding operations and dairies located in the watershed with associated "manure utilization areas", fields to which manure is applied.

Figure 17. Silviculture

Most of the TMDL watershed is forested, and much of this is managed for timber harvesting. There were large tracts of land being clear cut and offered for sale for development in the southern extent of subwatershed 100 (pictured left and below left). Some logged areas revealed significant land disturbance which may contribute to runoff of pollutants (below).

Figure 18. Mining and Industry

There are several mines, quarries, and areas of industrial development in the TMDL watersheds, especially in the southern portion of subwatershed 100. While these should not be a direct cause of bacteria loading to streams, they do represent area of land disturbance and impervious surfaces that contribute to nonpoint source runoff.

Figure 19. Trash in Streams

The amount of trash deposited directly into and alongside streams in the watershed is substantial. While it is uncertain how much this may contribute to instream bacteria, it is likely to have both direct (bacteria from decomposing food, diapers, etc.) and indirect (feces from scavenging wildlife) effects. This would be an obvious and uncomplicated source to address in a TMDL implementation plan.

Figure 20. Subwatershed 050 (Upper) Source Assessment

Land draining to Cow Castle Creek and eventually to E-050 is almost evenly split between agricultural uses and forested land. The headwaters of Cow Castle Creek originate near the City of Orangeburg, but this area retains a rural character and most housing here is likely on septic systems.

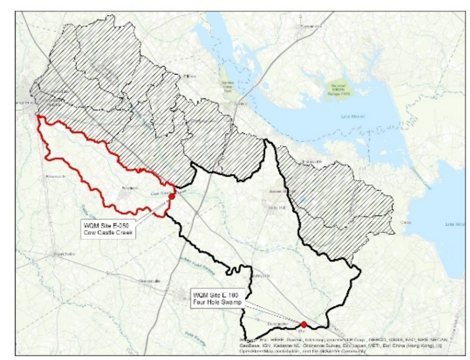

Figure 21. Subwatershed 050 (Lower) Source Assessment

Agricultural land uses predominate in the southeastern portion of the watershed. Most of the AFOs and manure utilization areas are located here. Row crops seen at the time of the site visit included corn and cotton.

Figure 22. Subwatershed 100 (Upper) Source Assessment

Subwatershed 100 is predominantly forested. There are a few small towns, some agriculture, mining, and industrial operations. A major inland port is planned for the upper northwestern portion of the watershed which is expected to bring development to this area.

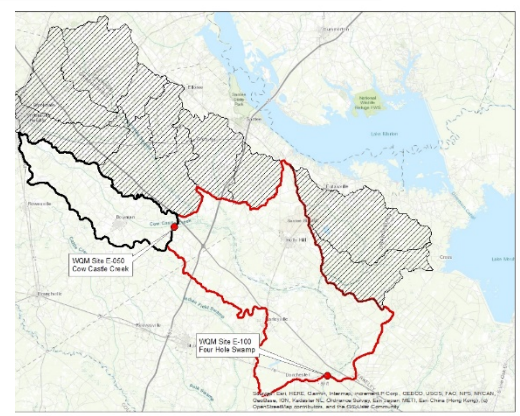

Figure 23. Subwatershed E-100 (Lower) Source Assessment

Forests and forestry occupy much of this part of the watershed. There are some mines, hobby farms, row crops, AFOs and manure utilization areas here as well. Large tracts of land were being cleared and offered for sale for development at the southernmost extent near the new Volvo plant.