2014 Murrells Inlet Watershed Plan

A Community-Based Management Plan to Address Fecal Coliform Impairments in Local Shellfish Harvesting Areas

WACCAMAW REGIONAL COUNCIL OF GOVERNMENTS

Funded by USEPA Section 319 and 604(b) Grants through SC DHEC
Submitted to SC DHEC by the Waccamaw Regional Council of Governments.

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Acronyms and Abbreviations

The following is a list of abbreviations and acronyms utilized in the text of this plan document that refer to state and federal agencies, terms related to laws and regulations, and other common phrases related to water quality management.

BMP- *Best Management Practice*

CDC- *Center for Disease Control and Prevention*

CMOM- *Capacity, Management, Operations, and Maintenance*

CWSEC- *Coastal Waccamaw Stormwater Education Consortium*

FDA- *United States Food and Drug Administration*

HUC- *Hydrologic Unit Code*

LID- *Low Impact Development*

ml- *Milliliter*

MGD- *Million Gallons per Day*

MPN- *Most Probable Number*

MS4- *Municipal Separate Storm Sewer System*

NOAA- *National Oceanic and Atmospheric Administration*

NOS- *National Ocean Service*

NLCD- *National Land Cover Data*

NPDES- *National Pollutant Discharge Elimination System*

SC DHEC- *South Carolina Department of Health and Environmental Control*

SC DNR- *South Carolina Department of Natural Resources*

SCORE- *South Carolina Oyster Restoration and Enhancement*

SFH- *Shellfish Harvesting Waters*

SWPPP- *Stormwater Pollution Prevention Plan*

TMDL- *Total Maximum Daily Load*

US ACE- *United States Army Corps of Engineers*

US EPA- *United States Environmental Protection Agency*

WSA- *Water and Sewer Authority*

WSD- *Water and Sewer District*

WWTF- *Wastewater Treatment Facility*

Acknowledgements

The opportunity to develop this watershed-based plan for Murrells Inlet was made possible by a Section 319 Grant awarded by SC DHEC. This planning effort was spearheaded by Murrells Inlet 2020. Several Murrells Inlet community members made significant contributions as steering committee members. Thanks to Jim Wilkie, Sandra Bundy, Gary Weinreich, and Lee Hewitt for providing invaluable insight regarding the history of Murrells Inlet and the economic and cultural importance of the estuary to the committee. Additional thanks to the Murrells Inlet Volunteer Monitoring Program, which has collected valuable water quality data in the Murrells Inlet estuary since 2008. Particular thanks to Gary Weinreich for his coordination of monitoring conducted in Georgetown County. Their dedicated efforts are greatly appreciated. Finally, thanks to Murrells Inlet 2020 for hosting the majority of our meetings at their office.

A significant portion of this plan required extensive technical assistance and data analysis. Stephen Williams of Earthworks Group, Inc. produced all of the major map inserts found in the document. These maps were vital in assessing existing conditions within the watershed and in evaluating priority areas for best management practice consideration. Thanks also to Heather Young and Dr. Susan Libes of Coastal Carolina University for performing a baseline assessment of fecal coliform data collected by SC DHEC's Shellfish Program. Their data analysis and reporting were the primary resources utilized by the steering committee to prioritize SC DHEC monitoring stations for water quality improvements. Stephen, Heather, and Susan were very responsive to all steering committee requests for further technical assistance as the planning process proceeded. Thanks for their tremendous contributions. Finally, thanks to Dr. Dan Hitchcock, Clemson University Baruch Institute of Coastal Ecology and Forest Science, who led several site visits to evaluate potential opportunities for implementing stormwater best management practices. His technical expertise was also very beneficial.

Throughout the planning process several information requests were sent out to various agencies and institutions throughout the state. Thanks to Wade Cantrell, Banu Varlik, Amy Bennett, and Mike Pearson from SC DHEC, Nancy Hadley from SC DNR, Dr. Dwayne Porter from University of South Carolina, Dr. Keith Walters from Coastal Carolina University, Kim Jones from the Town of Bluffton, Tommy Kennedy from Georgetown County Water and Sewer District, and Neeraj Patel from Grand Strand Water and Sewer Authority for supporting this planning effort by providing useful information from their respective agencies. Thanks to Coastal Carolina University for allowing the steering committee to setup a Cloud Site as an access portal for all of the references and draft reports.

Additional thanks to Dave Fuss from Horry County Stormwater and Tracy Jones from Georgetown County Stormwater for their role on the project steering committee. They have steadfastly supported the need for the watershed plan and were integral in all aspects of the process including the review of the final document. It has been a pleasure to work with all of the steering committee members. Their commitment to protecting the water quality and natural resources of Murrells Inlet is commendable.

Dan Newquist
Planner, Waccamaw Regional Council of Governments

Executive Summary

Introduction

Murrells Inlet is a coastal community with strong economic and cultural ties to the salt marsh estuary that bears its name. The natural resources in Murrells Inlet attract residents and visitors to numerous outdoor recreation activities including bird watching, boating, fishing, shellfish harvesting, hiking, etc. The local commercial fishing industry helps support a vibrant restaurant scene, which has led Murrells Inlet to become regarded as the "Seafood Capital of South Carolina". Protecting and sustaining these natural resources is of paramount importance to the Murrells Inlet community. This watershed plan serves as a means to guide the implementation of best management practices based on water quality trends and current landscape conditions. The primary focus of this watershed plan is to assess and mitigate sources of bacteria pollution in Murrells Inlet.

Below are the main overarching goals that guided the watershed planning process and serve as the ultimate measure of success for the Murrells Inlet community:

- ***Identify sources of fecal coliform bacteria impacting the water quality in and around the Murrells Inlet oyster beds.***
- ***Over a 20 year period, aim to improve water quality by reducing the level of fecal coliform entering Murrells Inlet and achieve a target of 80% of all SC DHEC designated shellfish acres, excluding those administratively designated as Prohibited, as an Approved or Conditionally Approved classification.***
- ***Continue to highlight the history of the fisheries industry in Murrells Inlet and promote the cultural, economic, and outdoor recreational benefits associated with sustaining viable shellfish harvesting opportunities in the community.***
- ***Increase public awareness regarding the environmental sensitivities of the local shellfish harvesting areas and promote ways by which individuals and the community as a whole can protect local water quality.***

The Murrells Inlet watershed extends from the Huntington Beach State Park and North Litchfield portions of Georgetown County to the Garden City Beach and the southern tip of Surfside Beach in Horry County along the Hwy 17 corridor. The watershed area is approximately 9,313 acres or 14.55 square miles in its entirety. SC DHEC estimates that 3,108 acres within the watershed are suitable habitat for the production of shellfish. Through an analysis of drainage characteristics, 51 distinct subwatersheds drain into Murrells Inlet ranging in size from 5 acres to 633 acres.

Regulatory Framework

South Carolina Department of Health and Environmental Control (SC DHEC) has classified the entire Murrells Inlet estuary as a Shellfish Harvesting Area water of the state. Shellfish Harvesting Areas are held to the highest water quality standard for fecal coliform bacteria (a geometric mean of 14MPN/100ml and an est. 90th percentile of 43MPN/100ml). This standard is established by the Food and Drug Administration to help protect the public from food-borne illnesses associated with the consumption of raw shellfish.

Through the state Shellfish Program, SC DHEC collects water quality samples on a monthly basis at 25 locations throughout Murrells Inlet. The results determine whether areas within Murrells Inlet are approved for shellfish harvesting. As required by state law, SC DHEC administratively classifies a total of 155 acres (5% of total area) as Prohibited, in the three areas in Murrells Inlet with marina establishments. Presently, the vast majority of Murrells Inlet (2217 acres of 71% of total area) meets the fecal coliform water quality standard and is approved for shellfish harvesting.

While the majority of Murrells Inlet meets the stringent fecal coliform standards for Shellfish Harvesting Areas, in 2005 SC DHEC drafted a Total Maximum Daily Load (TMDL) report for the Murrells Inlet watershed identifying eight monitoring sites that failed to meet the fecal coliform standard. The TMDL identifies non-point sources of pollution as the main contributor and established an ~80% reduction in bacteria loads in order to comply with the water quality standard.

Bacteria Source Assessment

Given the varied landscapes across the watershed, the contributing sources of bacteria can differ significantly from one area of Murrells Inlet to another. Several potential bacteria sources were identified based on available data, community stakeholder input, and information provided by various management agencies. Wildlife and waterfowl are the largest contributing sources of fecal coliform in the Inlet. Pet waste is considered to be the second largest source. Septic systems, sewer infrastructure, and illicit boat discharges are not believed to be contributing factors. However, the report does recommend some focused monitoring to confirm a few isolated areas with septic system concern and to inspect the sewer pump station inventory.

Rainfall events transport fecal coliform bacteria to the Inlet via stormwater runoff through the extensive network of drainage ditches and pipes. Bacteria readings are compounded by a few other issues such as small mammals (raccoons, possums, etc) which migrate to the ditches for water sources and utilize them as pathways. Bacteria are also known to attach to sediments, which also get transported downstream. Increased siltation is occurring on the north and south ends and along Parsonage Creek. In areas of heavy siltation, there is limited saltwater flow to dilute and flush away the bacteria and less salinity to kill the bacteria.

Another factor that may influence high bacteria levels is existing and increasing residential development. The south-end of the watershed is less developed meaning fewer impervious surfaces which allow for bacteria die-off or infiltration into the soil before being washed into the inlet. However, the wildlife and waterfowl concentration on the south-end is higher because these natural habitats become a migration point for other animals from the developed areas in the Inlet. Areas of the Inlet's east and west shorelines, and on the north-end, have greater development resulting in more impervious surfaces. These impervious surfaces cause the water carrying the bacteria to arrive in the Inlet more quickly without natural filtration. Additionally, more fresh water inputs into the inlet reduce salinity which allows bacteria to survive longer.

Local knowledge and available monitoring data enabled the steering committee to confidently make the above general conclusions regarding bacteria sources in Murrells Inlet. However the steering committee found it difficult to determine specific loads for each source based on existing resource management agency data. Therefore, estimated loads were used. The committee requests that SC DHEC invest resources to analyze bacteria sources at its shellfish monitoring stations and use this information and more sophisticated fate and transport hydrodynamic models to revise the TMDL and determine load allocations for each major source at key locations. This would help ensure the best chance of success for BMP implementation.

Best Management Practice Recommendations

Since there are multiple potential bacteria sources and the primary transport mechanism is via stormwater runoff a multifaceted management approach is needed. Some of the management strategies are structural such as the installation of rain barrels and incorporating constructed wetlands and bioretention systems across the landscape. Other best management practices are non-structural which may entail targeted public outreach, for example, efforts to improve proper pet waste disposal. Also, while many of the proposed best management practices can be applied across the watershed, several of the proposed management strategies are intended for a specific subwatershed based on the land use and drainage characteristics of that particular area of the community.

This watershed plan identifies several best management practices (BMPs) with varying implementation timeframes. Many BMPs will require the cooperation of multiple management agencies. Others will entail participation from the general public and the local business community. Most of the structural BMPs are intended to improve water quality at the priority monitoring stations identified in the watershed plan. Cost estimates are provided for most of the recommended BMPs. Finally, the plan includes a detailed outline of public outreach and future monitoring needs, both of which are essential to sustaining and evaluating the long-term success of all proposed watershed management initiatives and strategies.

Element A: Description of Murrells Inlet Watershed

Element A: Description of the Murrells Inlet Watershed

Introduction

The Murrells Inlet community was settled in the early 19th century and has always had a strong maritime culture, maintaining a lasting reputation as the Seafood Capital of South Carolina. Today, Murrells Inlet remains a vibrant waterfront community with several restaurants, shops, marinas, pedestrian boardwalks and public boat landings, making it a regional hub for outdoor water-based recreation. Local residents and business owners recognize the uniqueness of Murrells Inlet and are dedicated to preserving the natural resources that are so vital to the community. This watershed-based plan represents a community vision and long-term action plan to protect the shellfish harvesting areas within Murrells Inlet and the safety of the public when enjoying these natural resources.

Figure A-1 *The Murrells Inlet community is proud of its distinction as the Seafood Capital of South Carolina (Photo courtesy of Dr. Dan Hitchcock, Clemson University)*

Like most other coastal watersheds, population growth and associated development pressures have steadily influenced the natural hydrology and surrounding landscapes in the Murrells Inlet area. As these changes continue to occur, implementing appropriate land use and water resource management practices are essential to protecting the shellfish harvesting areas within the estuary.

A recent economic impact study completed by Coastal Carolina University, conservatively places the economic value of the Murrells Inlet waterfront marsh at $720 million. The report attributes the marsh as bolstering several sectors of the local economy including retail sales, particularly restaurant establishments; real estate property values; boating; fishing; accommodations and other tourism activities. This economic activity generates substantial tax revenues for both Horry and Georgetown Counties.

This watershed plan is scientifically-based and combines the economic, cultural, and environmental interests of the marsh, which is the single most important asset to the Murrells Inlet community. The plan promotes sound management strategies to sustain the value of the marsh for future generations of Murrells Inlet residents.

Figure A-2 *Shellfish are an important commodity to Murrells Inlet's seafood industry, but also play a dynamic role in tidal estuary ecosystems as well. (Photo courtesy of SC DNR)*

A primary species of concern in this watershed plan is the Eastern Oyster (*Crassostrea virginica).* Oysters are a distinct part of the local heritage and according to South Carolina Department of Health and Environmental Control's (SC DHEC) Shellfish Program, Murrells Inlet is widely recognized as the most economically important shellfish producing area along South Carolina's northern coast. Besides being valued as a commodity in the seafood industry, oyster reefs serve as vital elements in healthy and diverse estuarine ecosystems. As a keystone species, oysters form reefs that many other aquatic species depend upon as prime habitat. These reefs also affect water circulation and in many areas help prevent shoreline erosion. Oysters also have filtering capabilities which improve water quality and recycle nutrients (Tibbetts). Oyster harvesting is important to the maritime cultural identity of the Murrells Inlet community, therefore maintaining water quality that meets shellfish harvesting standards is a priority goal of this plan.

This watershed plan is a product of a yearlong iterative process facilitated by the Waccamaw Regional Council of Governments between key stakeholders representing Georgetown County, Horry County, Murrells Inlet 2020, Grand Strand Water and Sewer Authority, Georgetown County Water and Sewer District, and many others. Input was sought from concerned citizens throughout the Murrells Inlet community. Faculty and staff from Coastal Carolina University (CCU) conducted a detailed analysis of historical water quality data collected by SC DHEC and the Murrells Inlet Volunteer Monitoring Program. The Earthworks Group, Inc. provided spatial analysis technical assistance and produced several mapping exhibits of the Murrells Inlet watershed included in the document. CCU and The Earthworks Group, Inc. staff members were both fully engaged in all other stakeholder level aspects of the planning process as well. Additional consultation was sought from University of South Carolina, Clemson University, North Inlet-Winyah Bay National Estuarine Research Reserve, South Carolina Department of Natural Resources (SC DNR), National Oceanic and Atmospheric Administration (NOAA), US Army Corps of Engineers, and the Town of Bluffton.

Below are the main overarching goals that guided the watershed planning process and serve as the ultimate measure of success for the Murrells Inlet community:

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- ***Continue to highlight the history of the fisheries industry in Murrells Inlet and promote the cultural, economic, and outdoor recreational benefits associated with sustaining viable shellfish harvesting opportunities in the community.***
- ***Increase public awareness regarding the environmental sensitivities of the local shellfish harvesting areas and promote ways by which individuals and the community as a whole can protect local water quality.***

The first portion of the plan provides a detailed description of the Murrells Inlet watershed, along with additional background information on the Eastern Oyster. The plan then gives an overview of the laws and regulations pertaining to Shellfish Harvesting Areas in South Carolina along with a regulatory status summary for the Murrells Inlet estuary. The next section is a baseline assessment of historical water quality trends at each SC DHEC monitoring station located in Murrells Inlet.

The remainder of the plan outlines a comprehensive list of recommended best management practices for implementation in Murrells Inlet. This chapter is supplemented by an assessment of potential funding sources available for implementation. The watershed plan also emphasizes the importance of long-term monitoring and prioritizes locations and monitoring techniques to ensure that future water quality trends are carefully analyzed. Finally, the plan provides an overview of the public outreach efforts of this planning process and summarizes the targeted education strategies that will be pursued moving forward.

Figure A-3 *The steering committee reviewed several maps and conducted site visits to assess potential water quality concerns in the Murrells Inlet watershed. (Photos courtesy of Murrells Inlet 2020 and Daniel Newquist, Waccamaw Regional COG)*

Watershed Description

Murrells Inlet is a saltwater tidal estuary along the northeast coast of South Carolina. The watershed extends from the Huntington Beach State Park and North Litchfield portions of Georgetown County to the Garden City Beach and the southern tip of Surfside Beach in Horry County along the US Highway 17 corridor. The inlet is approximately 5.5 nautical miles north to south in length and 1.0 to 1.5 miles wide east to west from the main channel jetty to the Marsh Walk waterfront district. The tidal range varies from 4.2 to 4.5 feet with an increase during the spring tide period of 4.7 to 5.3 feet. There are several tidal creeks and manmade canals that comprise the Murrells Inlet estuary, including Main Creek, Allston Creek, Parsonage Creek, Garden City Canal, Oaks Creek, Whale Creek, and Woodland Creek (SC DHEC 2013 Shellfish Report). **Exhibit A-1** is a general map of the entire Murrells Inlet watershed.

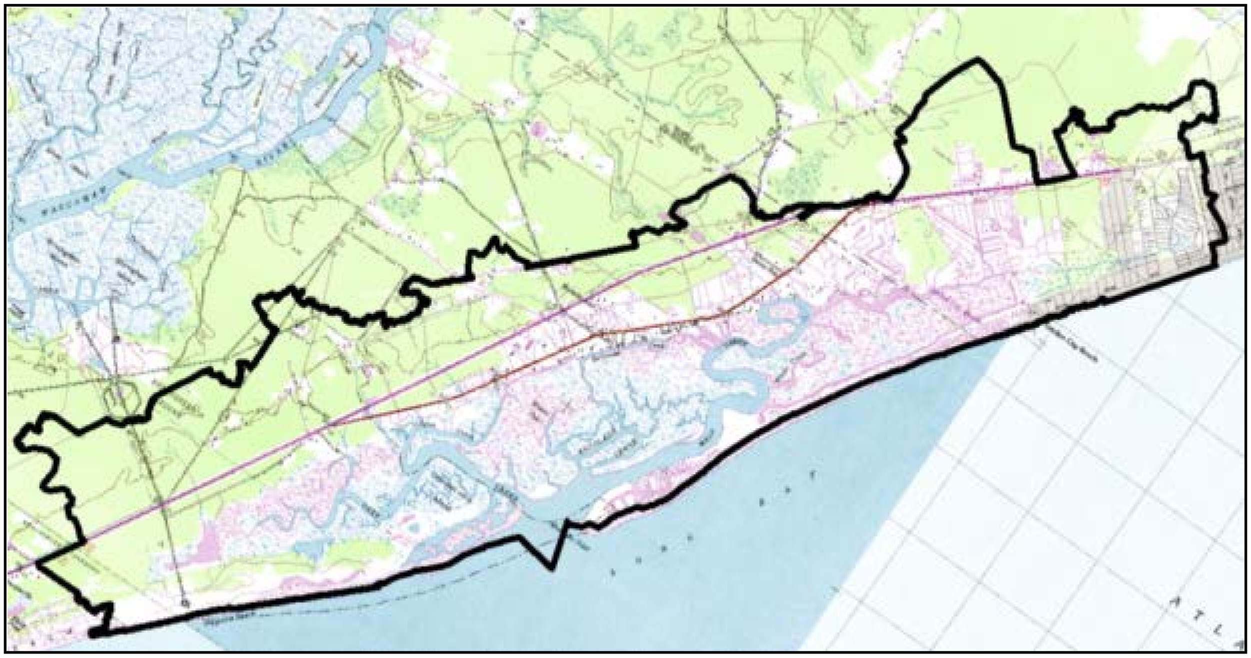


Exhibit A-1 *General Map of the Murrells Inlet Watershed (Produced by Stephen Williams, Earthworks Group, Inc)*

Based on NOAA tidal information and LiDAR data indicating total estuary land area and channel depth, it is estimated that the diurnal tide causes approximately 2.8 billion gallons of sea water to enter and leave the inlet every 12.5 hours. This tidally-driven exchange of clean sea water provides a constant flushing effect on the inlet and the oyster beds. This effect is most pronounced in the deeper areas in the central portion of the inlet. As a result, these areas consistently meet the shellfish water quality standards. The cleansing effect of this tidal water exchange is naturally less pronounced at the extreme north and south ends of the inlet and near the shorelines. In these areas, the tidal exchange becomes more limited, due in part to sedimentation and siltation. Additionally, stormwater containing bacteria runs off the land and into the shallower portions of the inlet where less tidal flushing occurs to dilute and kill incoming bacteria. This results in higher bacteria levels in these shallower portions of the inlet.

The entire Murrells Inlet estuary watershed is approximately 9,313 acres, or 14.55 square miles. Of this total, roughly 6,322 acres is land draining into the estuary, with the remaining acreage consisting of open water, intertidal mudflats and marsh habitat typical of estuaries in the Southeast. SC DHEC estimates that 3,108 acres within the watershed are suitable habitat for the production of shellfish. The watershed consists of a wide range of land uses including high density residential, single family residential, commercial, open space, and waterfront uses such as docks and marinas. The vast undeveloped areas are primarily concentrated in the southern end of the watershed at Brookgreen Gardens and Huntington Beach State Park, which are both significant natural and cultural landmark attractions in the region.

Due to the variety of land uses and drainage patterns observed across the Murrells Inlet area, subwatersheds were delineated using topographic data from LiDAR and local knowledge of storm sewer infrastructure to examine water quality conditions on a smaller scale. **Exhibit A-2** is a map displaying all 51 subwatersheds that comprise the greater Murrells Inlet estuary drainage area. A map of each subwatershed with detailed topographies and drainage is included in **Appendix A.** Each subwatershed includes a name that corresponds to a local street or landmark. **Table A-1** is a list of all of the subwatersheds delineated in **Exhibit A-2**. The table includes an approximate subwatershed acreage; a curve number, which assesses land surface infiltration and runoff characteristics; the flow rate typical of a 2 year storm event (calculated as 4.4 inches of precipitation in a 24 hour period for the Murrells Inlet area); and length of flow path from the upper reaches of each subwatershed to the final discharge point into the estuary. There are 25 subwatersheds without a flow path length due to their location along the Murrells Inlet shoreline where runoff typically enters the inlet via overland sheet flow. Some flows entering Murrells Inlet ultimately are also attributable to groundwater baseflow discharges.

Figure A-4 and **Figure A-5** below display the varied landscape contrasts across the Murrells Inlet watershed.

Figure A-4 *Southern end of the estuary with Huntington Beach State Park in the background. (Photo courtesy of Daniel Newquist, Waccamaw Regional COG)*

Figure A-5 *Northern end of the estuary with Garden City Beach in the background.* *(Photo courtesy of Daniel Newquist, Waccamaw Regional COG)*

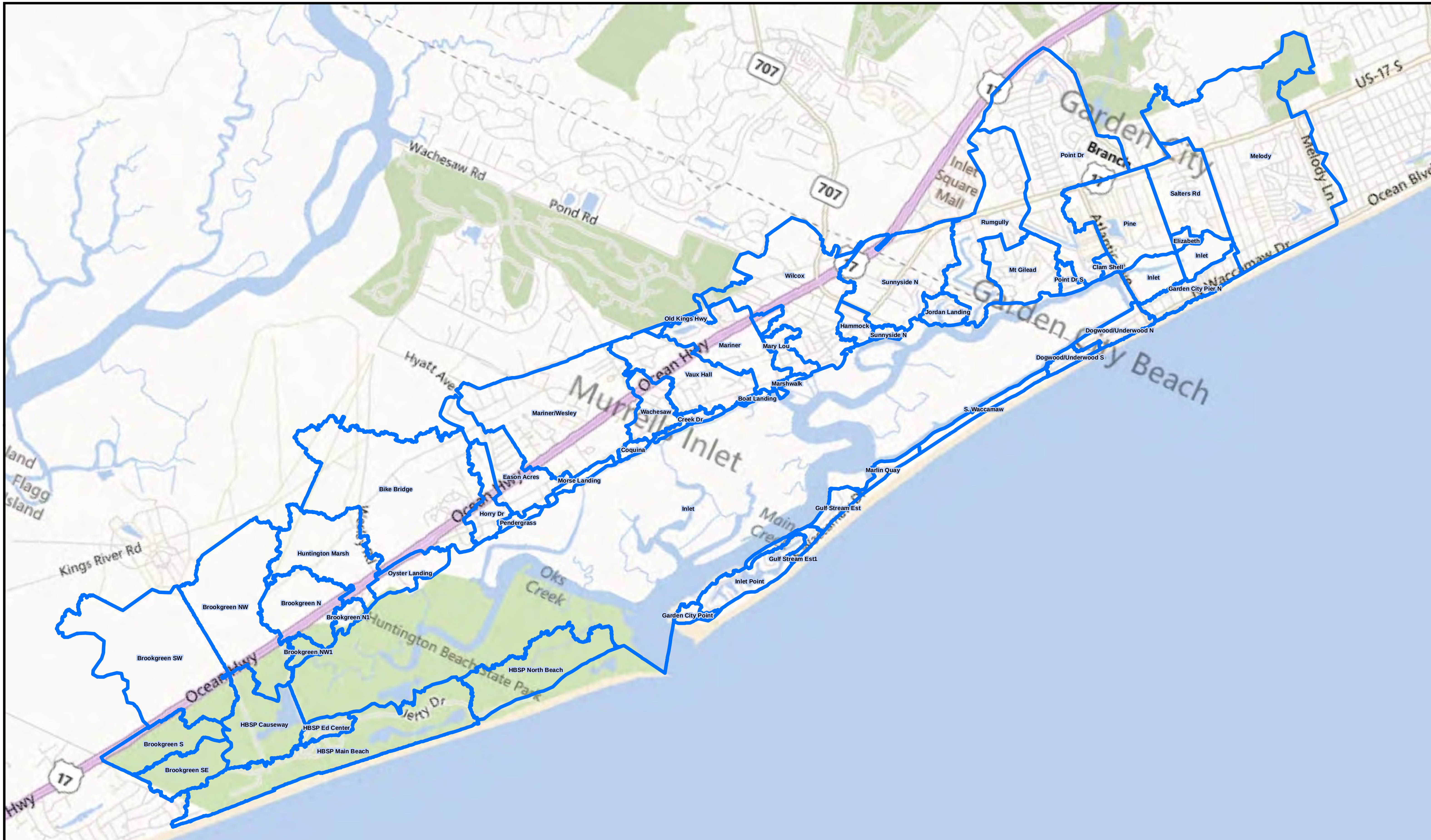
The subwatershed analysis approach provided the steering committee with a better understanding of how the fecal coliform monitoring data are related to the characteristics of adjacent subwatersheds; thus enabling the steering committee to identify where appropriate Best Management Practices (BMPs) are most beneficial. A more detailed description and analysis of the priority subwatersheds is provided in **Element D, Fecal Coliform Trend Analysis** and **Element F, Targeted Subwatershed Load Reductions**.

Natural Geomorphology- Coastal Processes

Although the Murrells Inlet watershed is a relatively small geographic area, this estuarine system is influenced by natural processes that occur on a much larger scale. It is important to have a general understanding of the unique natural features that comprise the Murrells Inlet estuary and how they are influenced by both single weather events such as hurricanes and other coastal processes along the South Atlantic Coast that occur over a long period of time.

Long-time residents have observed many distinct landscape changes over the years. As an example, prior to the construction of the jetties in the late 1970s there were two entrances into the main creek of Murrells Inlet (Douglass 1985). Locals also have noticed many changes on a much shorter timescale. Several tidal creeks have become shallower in recent years, likely caused by sedimentation deposited by tributary creeks and from shoreline erosion. Army Corps of Engineers studies also indicate that the tidal exchange and sediment pathway exchange between the Murrells Inlet estuary and the Atlantic Ocean has been altered as a result of the construction of the jetties (US ACE 2002). Ultimately, a concern is that fecal coliform and other bacteria survive longer in waterbodies with lower salinity levels and the accumulating sediment loads can provide favorable conditions for bacteria survival and propagation. Landscape-modifying processes such as drainage hydromodification, siltation, and jetty construction, all common to coastal areas need to be evaluated when considering various management options, including sediment reduction and dredging.

Figure A-6 *Historic photo circa 1940 of Garden City Beach and Murrells Inlet. Development and natural processes have altered the landscape over time. (Photo courtesy of the Georgetown County Library System.)*



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MAP TITLE:
MURRELLS INLET WATERSHED INVENTORY

PROJECT TITLE:
MURRELLS INLET WATERSHED MANAGEMENT PLAN

DATE:
05/16/2013

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121108.000:E

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SCALE:
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0 1,500 3,000
FEET

PROJECT LOCATION:
MURRELLS INLET
GEORGETOWN COUNTY
SOUTH CAROLINA

Exhibit A-2

Table A-1. Subwatersheds Draining into the Murrells Inlet Estuary											
#	Basin Name	Acres	Curve Number	Flow Path Length	Discharge Rate	#	Basin Name	Acres	Curve Number	Flow Path Length	Discharge Rate
1	*Melody*	632.97	76	12081.32 ft	58.6	*27*	*Oyster Landing*	56.53	52	2866.88 ft	8.1
2	*Bike Bridge*	507.98	49	10536.66 ft	103	*28*	*Mary Lou*	47.71	80	4785.97 ft	37
3	*Point Drive*	433.67	87	11680.53 ft	97	*29*	*Dogwood N*	42.58	77	Overland	
4	*Mariner/ Wesley*	408.82	73	8250.53 ft	106	*30*	*S Waccamaw*	34.57	53	Overland	
5	*Brookgreen SW*	394.50	45	12433.27 ft	5.3	*31*	*Jordan Landing*	32.66	60	2054.29 ft	11
6	*HBSP Main Beach*	323.77	53	11106.46 ft	12.1	*32*	*Hammock*	29.07	70	2444.07 ft	19
7	*Wilcox*	315.25	70	7189.04ft	19	*33*	*HBSP Ed Center*	27.23	70	Overland	
8	*Brookgreen NW*	304.58	45	8734.90 ft	5.1	*34*	*Gulf Stream Estates*	25.97	54	Overland	
9	*Rum Gully*	243.21	69	10427.42ft	48	*35*	*Gulf Stream Estates 1*	20.95	54	Overland	
10	*Sunny Side N*	231.90	66	5483.09 ft	71	*36*	*Brookgreen N1*	20.21	71	Overland	
11	*Pine*	190.38	78	6152.61 ft	99	*37*	*Dogwood S*	19.60	59	Overland	
12	*Huntington Marsh*	182.62	67	6633.22 ft	30	*38*	*Brookgreen NW1*	19.34	32	Overland	
13	*HBSP North Beach*	171.34	23	Overland		*39*	*Marlin Quay*	19.01	67	Overland	
14	*Vaux Hall*	171.07	79	5901.10 ft	86	*40*	*Creek Dr.*	17.86	66	Overland	
15	*HBSP Causeway*	151.75	44	Overland		*41*	*Morse Landing*	17.45	75	Overland	
16	*Mariner*	144.84	80	5376.59 ft	85	*42*	*Point Drive S*	15.39	84	Overland	
17	*Salters Rd*	143.53	84	4642.73 ft	157	*43*	*Out*	15.23		Overland	
18	*Brookgreen N*	133.15	45	5225.25 ft	3.6	*44*	*Garden City Point*	14.52	52	Overland	
19	*Eason Acres*	125.70	73	7532.72 ft	55	*45*	*Pendergrass*	11.66	53	Overland	
20	*Mt. Gilead*	115.45	74	3591.14 ft	55	*46*	*Elizabeth*	10.49	71	Overland	
21	*Brookgreen S*	100.93	59	5951.92 ft	5.6	*47*	*Coquina*	10.10	54	Overland	
22	*Brookgreen SE*	83.80	59	4343.33 ft	5.3	*48*	*Hammock1*	10.09		Overland	
23	*Inlet Point*	78.37	37	Overland		*49*	*Clam Shell*	8.92		Overland	
24	*Garden City Pier N*	67.24	85	Overland		*50*	*Marshwalk*	7.43	86	Overland	
25	*Wachesaw*	67.16	81	4064.63	60	*51*	*Boat Landing*	4.79	61	Overland	
26	*Horry Dr.*	62.16	69	4259.48 ft	25						

Source: Data generated from mapping produced by Earthworks Group LLC

Shellfish Habitat and Public Health Concerns

Oysters have several traits that enable them to be resilient in varying conditions within intertidal estuarine systems. As a colonizing species they have high fecundity rates with a wide geographic distribution of offspring. They also display capabilities of being one of the initial occupiers of areas that have experienced changes in the physical environment, such as disturbances resulting from a large storm. Oysters are also characterized as ecosystem engineers with the ability to modify the existing physical surroundings to create a habitat niche that is more suitable for their own long-term survival (Tibbetts 2013).

While oyster populations are fairly adaptable to changing habitat conditions, in many stages of their life-cycle they are sensitive to certain environmental conditions. Eutrophic conditions due to excessive nutrient inputs are known to be lethal to oyster populations. Oyster larvae are sensitive to suspended sediments caused by siltation. Salinity levels are also known to influence development, reproduction, and feeding activity. Studies have shown that oysters grow well at a salinity level of 12.5 ppt or higher. Oyster growth is limited at salinities below 10.0 ppt and habitat is virtually non-existent below 5.0 ppt (Kennedy). While these low salinity levels are rarely observed in Murrells Inlet, it does emphasize the importance of maintaining adequate tidal flow through the Murrells Inlet estuary and minimizing stormwater runoff rates during heavy rain events.

Ecologically, oyster larvae require a suitable surface to build their reef habitats. Ideally, oyster shell should serve as the substrate for reef establishment. Other substrates such as concrete structures and shell from other species can be used to establish oyster reef habitats. Without proper management, as oysters are harvested the availability of a suitable natural reef substrate for juvenile oyster larvae becomes diminished. South Carolina Department of Natural Resources (SC DNR) has proactively managed an oyster shell recycling program, called South Carolina Oyster Restoration and Enhancement (SCORE), to help reestablish healthy oyster reef habitats across the state on an annual basis. In fact, through a partnership with Murrells Inlet 2020, the community is known for having established one of the most successful oyster shell recycling programs in the state. Further discussion on the importance of oyster reef restoration and maintenance is included in **Element E: Murrells Inlet Shellfish Assessment**. Also, since efforts such as the SC DNR SCORE program are dependent upon public awareness and participation, specific outreach recommendations are included in **Element J: Public Outreach and Education Resources.**

Figure A-7 *A strong partnership between SC DNR and Murrells Inlet 2020 has resulted in successful oyster shell recycling and habitat restoration efforts in the community. (Photo courtesy of Murrells Inlet 2020)*

One of the most significant factors influencing future shellfish harvesting activities from a public health standpoint is the presence of pathogenic bacteria in estuarine habitats. The indicator parameter that SC DHEC uses to evaluate water quality within designated Shellfish Harvesting Areas is fecal coliform concentrations. These standards are implemented nationwide under the guidance of the National Shellfish Sanitation Program overseen by the US Food and Drug Administration (FDA). The program is designed to ensure safe consumption of various shellfish products, including oysters which are frequently consumed raw. The water quality standards established to ensure safe shellfish consumption are the most stringent, being much lower than the bacteria water quality standard for recreational contact. Murrells Inlet is safe for all recreational contact uses and meets the Enterococci geometric mean standard of 35/100ml.

Fecal coliform bacteria are found in the intestines of warm-blooded animals, including humans, and serve as an indicator organism for the presence of other possible pathogens, including viruses. The presence of significant levels of fecal coliform in a waterbody indicates that a nearby source of animal or human waste has entered the environment or that contaminated sediments have been resuspended. Elevated levels of fecal coliform indicate the possible presence of other pathogenic organisms that can pose risks of disease transmission to humans who are exposed by ingesting contaminated raw shellfish. The most common waterborne diseases associated with high levels of pathogenic bacteria include *Giardiasis* and *Cryptosporidiosis.* According to the Centers for Disease Control and Prevention (CDC), *Giardia* is the most common intestinal parasitic disease in the United States. In 2010, the CDC reported 19,888 cases of *Giardiasis* nationwide. In comparison, the CDC reported 8,951 cases of *Cryptosporidiosis* in 2010. The main symptoms for both diseases include dehydration along with nausea, vomiting, fever, and diarrhea.

Another strand of bacteria, *Vibrio*, is raising public health concerns related to shellfish handling and consumption. According to SC DHEC's Bureau of Disease Control, the bacteria genus *Vibrio* normally live in warm seawater and can potentially contaminate oysters. *Vibrio* infections can be transmitted through raw consumption of oysters, with illness symptoms similar to *Giardiasis* and *Cryptosporidiosis*. *Vibrio* can also pose serious infection risks to people who are immunocompromised. Infections can be transmitted through a skin cut and may lead to skin breakdown and ulceration or even more serious complications.

The next element describes how SC DHEC manages Shellfish Harvesting Areas by following the regulatory guidelines set forth by FDA's National Shellfish Sanitation Program. **Element B** then provides a status summary of the current Shellfish Harvesting Area classifications and an overview of the Total Maximum Daily Load for Fecal Coliform in Shellfish Waters of the Murrells Inlet Estuary issued by SC DHEC in 2005.

Figures A-8 and A-9 *The Murrells Inlet is a very dynamic estuary system as displayed by the low-tide conditions in picture on left and the extreme high tide flooding conditions that occasionally occurs in Garden City Beach and other areas of the watershed seen in picture on the right. (Photos courtesy of Murrells Inlet 2020)*

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Element B: Water Quality Standards and Regualtions

Element B: Water Quality Standards and Regulations

This element provides an overview of the existing laws and regulations that apply to the management of waters classified as Shellfish Harvesting Areas in South Carolina. The element then reviews the existing regulatory status of the Shellfish Harvesting Areas located within the Murrells Inlet estuary. Finally, a summary review of the 2005 Murrells Inlet Fecal Coliform Total Maximum Daily Load (TMDL) document is also included. The ultimate goal of this watershed plan is to outline management strategies that will improve water quality in Murrells Inlet and increase the amount of acreage meeting the Approved or Conditionally Approved shellfish harvesting classification.

South Carolina Water Quality Standards

The Murrells Inlet estuary is located in one of 25 designated Shellfish Management Areas in the State of South Carolina. Murrells Inlet is in Management Area 04, which also includes the Litchfield-Pawleys Island Estuary, located immediately south of Murrells Inlet in Georgetown County. Of the 4,364 acres of habitat suitable for the production of shellfish in Management Area 04, 3,108 of them are located within the Murrells Inlet watershed. Of the 33 active monitoring sites in Management Area 04, 24 of them are located in the Murrells Inlet estuary (SC DHEC 2013 Shellfish Report). See **Exhibit B-1** on Page 17 for a map of SC DHEC Shellfish Management Area 04 with monitoring station locations. All waters within Murrells Inlet are regulated as Shellfish Harvesting Waters (SFH). South Carolina state Regulation 61-68, Water Classifications and Standards, defines Shellfish Harvesting Waters (SFH) as:

Tidal saltwaters protected for shellfish harvesting and uses listed in Class SA and SB. Suitable for primary and secondary contact recreation, crabbing, and fishing. Also suitable for the survival and propagation of a balanced indigenous aquatic community of marine fauna and flora.

SC DHEC is granted the authority to regulate the harvesting, sanitation, handling and processing of shellfish under state law outlined in Section 44-1-140 of the Code of Laws of South Carolina, 1976 and by rules set forth in state Regulation 61-47.

SC DHEC Shellfish Management Area 04: 2013 Annual Update

Every year SC DHEC issues a report for each Shellfish Management Area across the state that updates the classifications of designated Shellfish Harvesting Waters. In accordance with the FDA National Shellfish Sanitation Program, SC DHEC utilizes the previous three years of monitoring data to establish these regulatory classifications. A minimum of 30 samples at each monitoring station within this time period is required to meet FDA's standards. There are 36 sampling dates scheduled to ensure that there are a sufficient number of valid samples in case there is a laboratory or handling error. SC DHEC utilizes a systematic random sampling monitoring strategy to minimize bias with respect to tidal stage and weather conditions.

The designations that SC DHEC uses to classify Shellfish Harvesting Areas are Approved, Conditionally Approved, Restricted, and Prohibited. A brief description of each classification is provided below with the current number of acres of each classification as of the 2013 Annual Management Area 04 Shellfish Report. **Appendix C** provides a location description of each classification area as of the 2013 Annual Management Area 04 Shellfish Report. **Element D: Fecal Coliform Trend Analysis,** includes a summary of water quality regulatory status trends dating back to the 1992 Annual Update report for Shellfish Management Area 04.

Approved- These are areas that are normally open for the harvesting of shellfish and are safe for human consumption. Approved areas must not exceed the following water quality standards:

- *Not to exceed a Most Probable Number (MPN) geometric mean of 14/100 ml*
- *No more than 10 percent (%) of the samples exceed an MPN of 43/100 ml (Estimated 90th percentile)*

2,217 acres or 71% of the 3,108 total available shellfish acres in Murrells Inlet are currently Approved.

Conditionally Approved- These are areas that typically meet the criteria for Approved classification except under predictable conditions. Closure criteria and subsequent re-opening procedures are outlined in an area specific management plan. A high rainfall event is the most common condition that results in a temporary closure within a Conditionally Approved area.

Presently, SC DHEC does not manage any portions of the shellfish harvesting areas within Murrells Inlet as Conditionally Approved, mainly due to limited personnel resources. One of the recommendations included in **Element H: Watershed Management Measures,** is to evaluate shellfish harvesting areas within Murrells Inlet that would meet the water quality criteria and be good candidates for Conditionally Approved status, presuming additional SC DHEC resources are available and justified.

Restricted- These are areas that exceed the water quality standards for an Approved classification area and are normally closed to harvesting. Shellfish may be harvested and relayed to an Approved area for depuration via a special permit.

The fecal coliform numeric standard limits to relay shellfish located in Restricted Shellfish Harvesting Areas to Approved Shellfish Harvesting Areas are the following:

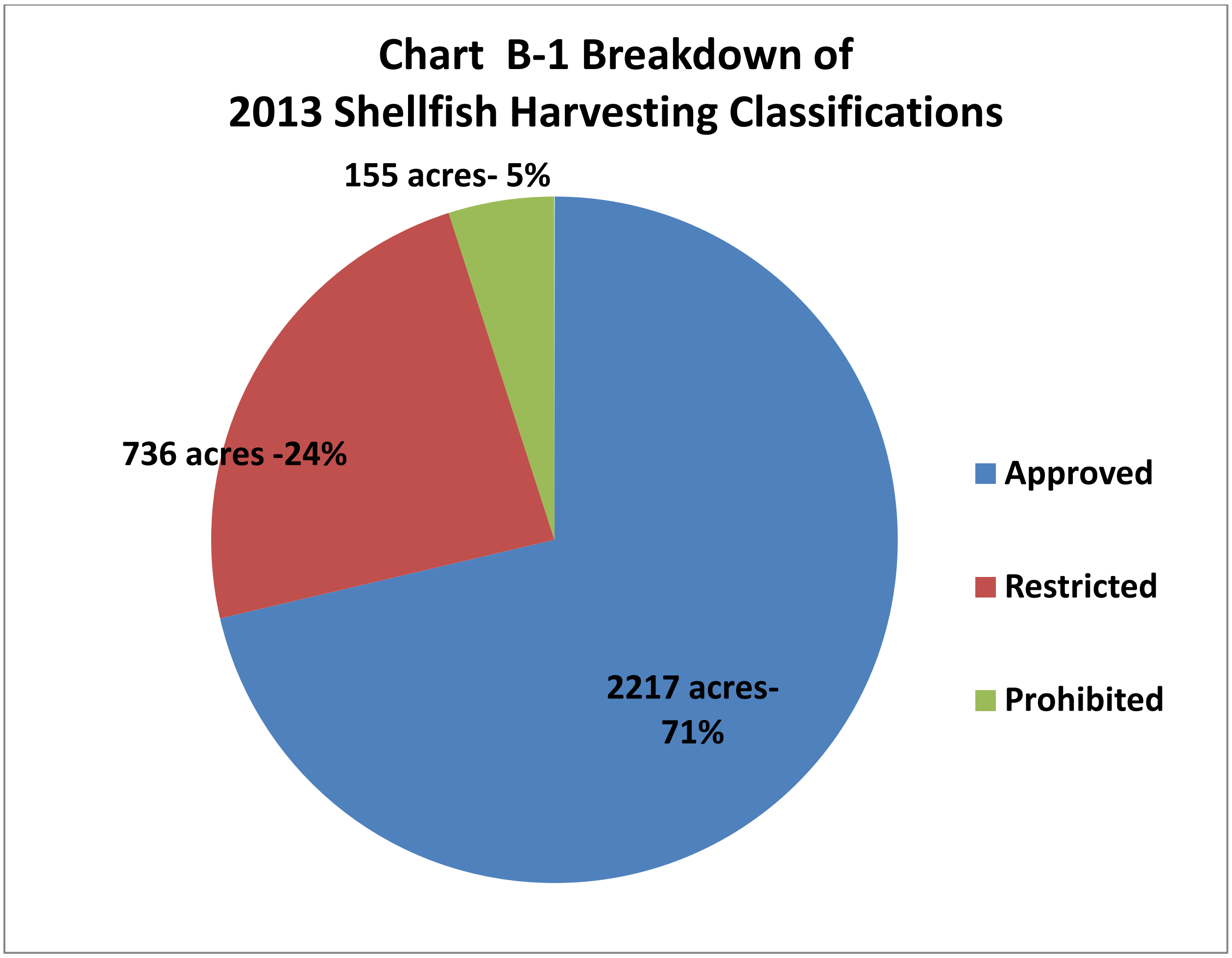
- *Not to exceed a Most Probable Number (MPN) geometric mean of 88/100 ml*
- *No more than 10 percent (%) of the samples exceed an MPN of 260/100 ml (Estimated 90th percentile)*

736 acres or 23.7% of the 3108 total available shellfish acres in Murrells Inlet are currently Restricted.

Prohibited- These are areas that are administratively closed to shellfish harvesting for any purpose related to human consumption. They are typically associated with areas adjacent to potential point sources of pollution such as a wastewater treatment plant, industrial site, or in the case of Murrells Inlet, marinas and docking facilities.

155 acres or 5.0% of the 3108 total available shellfish acres in Murrells Inlet are Prohibited by regulation due their proximity to marinas.

Chart B-1 provides a breakdown of the percentages of each classification within the Murrells Inlet watershed as of the 2013 Management Area 04 Annual Update.



The current ratio of Approved acreage versus Restricted and Prohibited acreage is well within the normal range of typical conditions found in estuaries along the coast of South Carolina. Therefore, comparatively speaking Murrells Inlet is in a good position to sustain local shellfish harvesting activities well into the future.

A location description for each active SC DHEC water monitoring station in Murrells Inlet is provided in **Table B-1** below:

Table B-1. SC DHEC Water Monitoring Stations in the Murrells Inlet portion of Shellfish Management Area 04.	
Station #	**Location**
04-01	Main Creek at Atlantic Avenue Bridge
04-02	Main Creek at Mickey Spillane's Home
04-03A	Southeast side of the Prohibited Zone near Captain Dick's Marina in Main Creek
04-03B	Northwest side of the Prohibited Zone near Captain Dick's Marina in Main Creek
04-04A	Garden City Canal due E of Entrance to Flagg Creek
04-04B	Northern Boundary of the Marlin Quay Closure Zone in Main Creek
04-04C	Western Boundary of the Marlin Quay Closure Zone in Main Creek
04-06	Allston Creek at Weston Flat
04-07	Allston Creek- Hughes Landing
04-08	Parsonage Creek at Nance's Dock
04-08A	Oyster (Carr) Landing at Huntington Beach State Park
04-16	Parsonage Creek at Chicken Farm Ditch
04-17A	Southwest Corner of the Voyager View Marina Prohibited Zone in Parsonage Creek
04-18	North Boundary of Clambank Flats POG
04-23	Main Creek at Oyster Cove
04-24	Oaks Creek at First Curve
04-25	Main Creek at Flagg Creek
04-26	Garden City Canal at the "Old Boat Wreck"
04-27	Main Creek, Opposite Entrance to Mt. Gilead Canal
04-28	Oak's Creek, Approximately 150 Meters from the Huntington Beach State Park Causeway
04-29	Oyster Cove South Branch
04-30	Oyster Cove North Branch
04-31	Woodland Creek- 100 Meters East of Mainland
04-32	Oak's Creek at Brigham Hole
Source: SC DHEC, Shellfish Management Area 04- 2013 Annual Update	

Exhibit B-1 is a map displaying the current shellfish harvesting classifications in Shellfish Management Area 04.

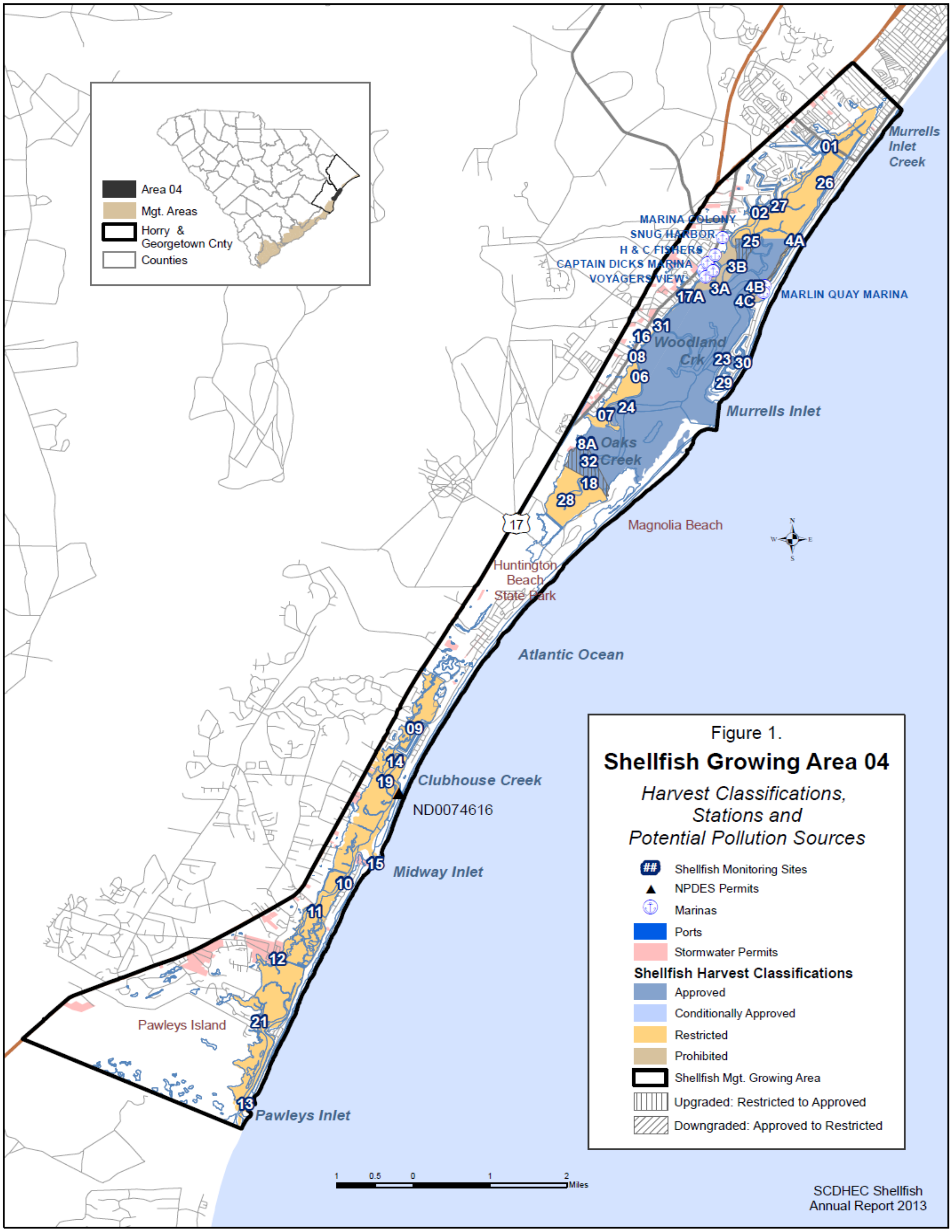


Exhibit B-1: *2013 Shellfish Classifications for SC DHEC Management Area 04*

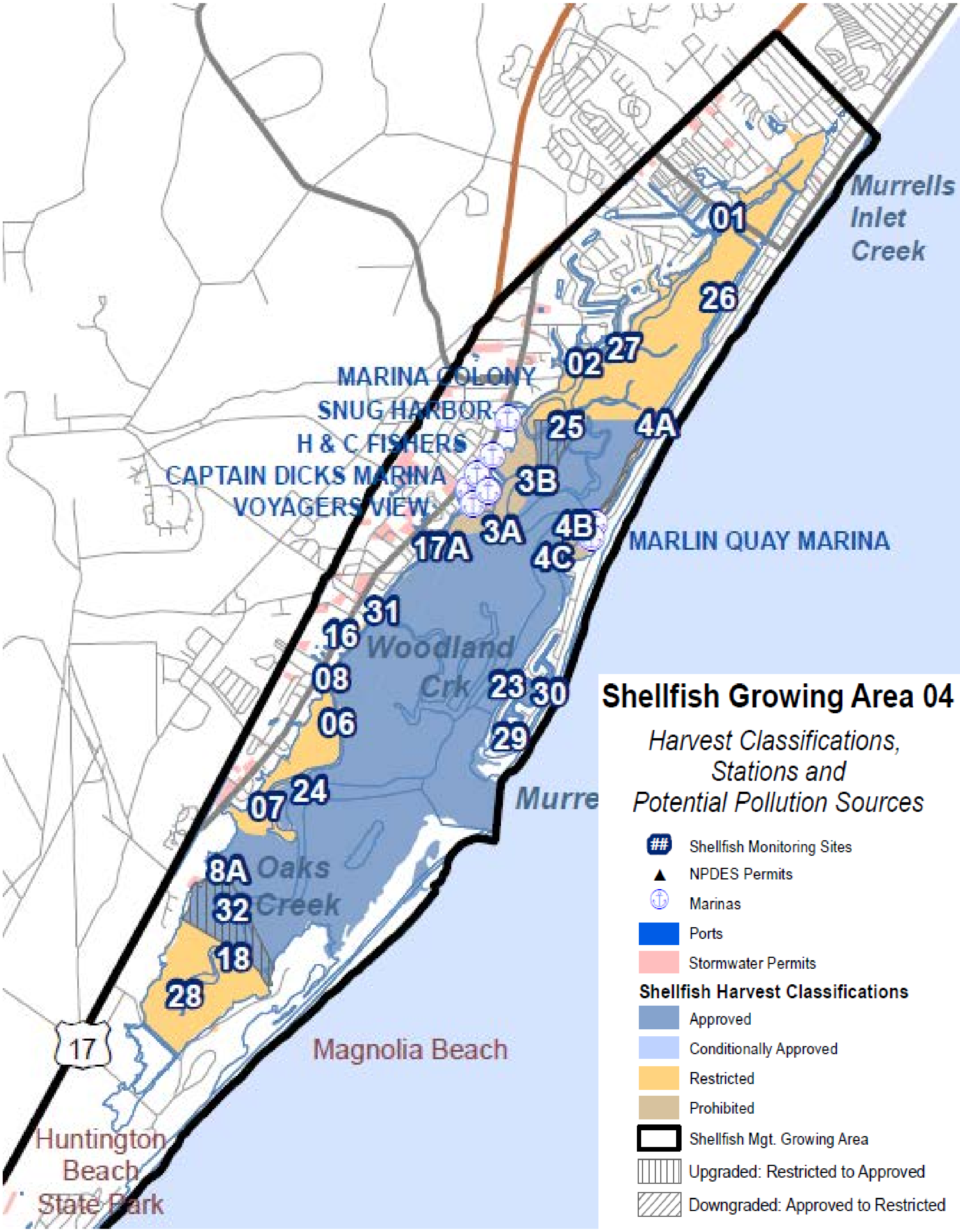


Exhibit B-2: *Murrells Inlet portion of Shellfish Management Area 04*

2005 Murrells Inlet Estuary Fecal Coliform Total Maximum Daily Load

In preparing the 2004 303(d) list of impaired water bodies, SC DHEC identified 8 out of 24 monitoring stations within the Murrells Inlet estuary that exceeded the water quality standards for fecal coliform bacteria. This led SC DHEC to the development of a TMDL for the Murrells Inlet estuary. A TMDL essentially determines the maximum amount of a pollutant that can be assimilated by a receiving waterbody without exceeding state water quality standards, in this case for waterbodies classified as Shellfish Harvesting Areas.

A description of the TMDL process on EPA's website is provided below:

> *A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant. Pollutant sources are characterized as either point sources that receive a wasteload allocation (WLA), or nonpoint sources that receive a load allocation (LA). Point sources include all sources subject to regulation under the National Pollutant Discharge Elimination System (NPDES) program, e.g. wastewater treatment facilities, some stormwater discharges and concentrated animal feeding operations (CAFOs). Nonpoint sources include all remaining sources of the pollutant as well as anthropogenic and natural background sources. TMDLs must also account for seasonal variations in water quality, and include a margin of safety (MOS) to account for uncertainty in predicting how well pollutant reductions will result in meeting water quality standards.*

Table B-2 below provides a list of monitoring sites that were included on the 2004 South Carolina 303(d) list of impaired waterbodies and subsequently in the Murrells Inlet Fecal Coliform TMDL. The Murrells Inlet TMDL calculations and findings are based on data collected by SC DHEC between September 2001 and August 2004. The table includes a summary of the geometric means and the percent of samples above the 43/100ml est. 90th percentile standard for each of the respective monitoring stations. Each of these eight sites exceeded the est. 90th percentile standard and all but monitoring stations 04-26 and 04-27 exceeded the geometric mean standard. The TMDL is also structured to focus on three separate segments of the estuary system including Main Creek, Parsonage Creek/Allston Creek, and Garden City Canal. **Element D** reviews the water quality trends for all of the monitoring stations located in Murrells Inlet.

Table B-2 Murrells Inlet SC DHEC Monitoring Stations on 2004 303(d) list			
Site #	**Location**	**Geometric Mean**	**% of Samples above 43 CFU/100ml**
Main Creek			
04-01	Main Creek at Atlantic Avenue Bridge	42.9	53%
04-01A	Main Creek at Stanley Drive	30.6	41%
04-27	Main Creek, Opposite Entrance to Mt. Gilead Canal	7.5	13%
04-02	Main Creek at Mickey Spillane's Home	13.4	22%
Garden City Canal			
04-26	Garden City Canal at the "Old Boat Wreck"	8.7	24%
Parsonage Creek/ Allston Creek			
04-08	Parsonage Creek at Nance's Dock	24.4	42%
04-16	Parsonage Creek at Chicken Farm Ditch	72.7	54%
04-06	Allston Creek at Weston Flat	14.7	25%
Source: SC DHEC, Total Maximum Daily Loads for Fecal Coliform in Shellfish Waters of the Murrells Inlet Estuary, South Carolina			

The TMDL load reductions are calculated by accounting for all waste load allocations from point sources of pollution, such as wastewater treatment plants or industrial sites, and all load allocations from various non-point sources of pollution, such as stormwater runoff. A margin of safety to account for uncertainties in the natural environment is also incorporated into the final TMDL calculation. Generally, Fecal Coliform TMDLs are expressed as reductions in colony forming units (CFUs) per day, or as percent reductions. The waste load allocation for this TMDL is set at zero since there are no permitted point source facilities that discharge effluent into receiving waterbodies of Murrells Inlet. Therefore the targeted load reductions established in the TMDL are exclusively from non-point sources of pollution. The potential non-point sources identified in the TMDL were as follows:

- *Urban and Suburban Runoff:* Due to the increased development in the surrounding Murrells Inlet area, stormwater runoff was identified as a potential fecal coliform source in the TMDL.
- *Individual Sewage Treatment and Disposal Systems (Septic Tanks):* The TMDL identified three small areas that were still being served by septic tanks. However, a SC DHEC survey conducted in 2004 only identified two malfunctioning systems out of a total of 119 known active septic systems in Murrells Inlet. The TMDL therefore did not consider septic systems or the area's sanitary sewer system to be likely and significant sources of pollution.
- *Wildlife:* The TMDL acknowledged that there are areas that support large populations of wildlife and waterfowl, particularly in the southern end of the watershed near Brookgreen Gardens and Huntington Beach State Park. These wildlife populations could be significant contributors to the fecal coliform levels

observed in Murrells Inlet. The TMDL estimates that there were 273 cats and 240 dogs residing in the watershed and therefore discounts pet waste as a significant source of fecal coliform.

- *Boat Traffic:* Given the significant level of marine activities in Murrells Inlet, the TMDL did acknowledge that onboard septage is a potential source of fecal coliform but based on a review of other studies conducted in Murrells Inlet, there was little evidence of any current impacts, and therefore was not believed to be a problem. There is not a significant amount of transient boat traffic in Murrells Inlet. Most boating activity is either day use or local commercial fishing.

Based on the TMDL results, the loading estimates for each impaired segment are outlined in **Table B-3.** The percent load reductions needed to meet the geometric mean and est. 90th percentile water quality standards are also included.

Table B-3 Estimated Average Daily Fecal Coliform Loadings and Percent Reduction Needed

Impaired Segment	Total Loading	% Reduction to Meet Geometric Mean *(1)*	% Reduction to Meet 90th Percentile *(2)*
Main Creek (04-01, 04-01A, 04-02, 04-27)	1.5x10^12	80.4%	76.5%
Parsonage Creek/Allston Creek (04-08, 04-16, 04-06)	3.4x10^11	53.5%	81.4%
Garden City Canal (04-28)	1.1x10^11	0.0%	71.4%

Source: SC DHEC, Total Maximum Daily Loads for Fecal Coliform in Shellfish Waters of the Murrells Inlet Estuary, South Carolina

TMDL footnotes: (1): The percent reduction needed to achieve the geometric mean standard at all stations within the impaired system. This value is based on the fecal coliform levels predicted by the model and, thus, will deviate from the measured in-stream values due to the simplifying assumptions made during model calibration.

(2): The average percent reduction (computed from station-specific percent reductions) needed to achieve the not to exceed standard.

TMDL Monitoring and Assessment Requirements included in SMS4 permits

Both Horry and Georgetown Counties are subject to conditions in SC DHEC's Municipal Separate Storm Sewer System (SMS4) General Permit to address stormwater discharges in urbanized areas within their jurisdiction, which includes a large portion of Murrells Inlet. A full description of the SMS4 General Permit is included in **Element G: Existing Infrastructure and Management Programs.**

The SMS4 General Permit was renewed on January 1st and requires permittees to develop a TMDL Monitoring and Assessment Plan within twelve months and must include the following information:

- *Monitoring locations, appropriate for representative data collection*

- *Explanation of why monitoring is being conducted for selected locations*
- *A description of whether the locations are representative and contribute to pollutant loads*
- *An indication the seasons during which sampling is intended*
- *The pollutant of concern or its surrogates, as a sampling parameter*
- *Description of the sampling equipment*
- *A rationale supporting the proposed monitored locations as reflective of water quality concerns to the Maximum Extent Practicable.*

Sampling must be initiated within eighteen months of the effective MS4 permit renewal date. The new SMS4 General Permit also requires permittees to develop a TMDL Implementation Plan within 48 months and address the following items:

- *Assessment of the monitoring data. Where long-term data is available, this assessment should include an analysis of the data to show trends;*
- *Prioritization of areas targeted for BMP implementation and underlying rationale;*
- *Structural and nonstructural BMPs to address the wasteload allocation. Permittees should include a brief explanation of why the BMPs are selected (e.g., expected load reductions or percent of capture)*

Post-TMDL Assessments

The Murrells Inlet TMDL was evaluated in detail as part of this watershed planning process. The project steering committee understands that the TMDL was intended to serve as a framing document for identifying areas within Murrells Inlet that are impaired and to help establish initial target goals for water quality improvement. The project steering committee seeks to continue to work closely with SC DHEC utilizing an adaptive management approach in Murrells Inlet as encouraged in the recently adopted TMDL for Wadboo Swamp and Cane Gully Branch:

The Department 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 Wadboo Swamp and Cane Gully Branch. As additional data and/or information become available, it may become necessary to revise and/or modify the TMDL target accordingly.

During the planning process the steering committee reviewed the 2005 Murrells Inlet TMDL with SC DHEC's TMDL staff and concluded:

- That the TMDL development procedures used by the EPA contractor differ from the preferred methods used today. In addition, documentation pertaining to the rationale, and inputs of the model used by the contractor are unavailable to duplicate the consultant's calculations and results.

- The TMDL only utilizes monitoring data from 2001-2004, which does not necessarily provide a representative data set to determine long-term water quality trends in Murrells Inlet.

This watershed plan includes a substantial amount of additional data and new information regarding the water quality trends and hydrological characteristics of Murrells Inlet warranting an evaluation of the need to revise the 2005 TMDL. The subwatershed delineations and land use coverages outlined in this plan are much more detailed, accurate, and current due to the availability of LiDAR-based topographic data and information of the subsurface stormwater infrastructure in Murrells Inlet. This enabled the project steering committee to assess areas of potential fecal coliform sources on a local scale and their pathways into Murrells Inlet. A trend analysis of SC DHEC data was conducted dating back to the initial period of record in 1967. New data sources, particularly the Murrells Inlet Volunteer Monitoring program have also become available, which may help refine source allocations and corresponding load reductions needed.

In addition, SC DHEC may utilize a cumulative probability model to calculate shellfish fecal coliform load reductions in newly issued fecal coliform TMDLs throughout the state. The project steering committee has worked closely with SC DHEC to update the estimated load reductions based on recent monitoring data and by utilizing this cumulative probability modeling technique as outlined in **Element F: Targeted Subwatershed Load Reductions**.

Finally, local resident knowledge and information gathered from partner management agencies was an integral part of this planning process. This dialogue has given the project steering committee a better insight regarding potential pollution sources cited in the 2005 TMDL from existing septic systems, various wildlife species populations, waterfowl, and pet waste that may be affecting water quality in Murrells Inlet. Further discussion and specific recommendations to revise the 2005 Murrells Inlet TMDL are included in the Administrative BMP section in **Element H: Watershed Management Measures.**

The next section **Element C: Evaluation of Potential Fecal Coliform Sources** provides a general assessment of the potential bacteria sources that may be affecting water quality. **Element D: Fecal Coliform Trend Analysis** follows with a much more detailed review of historic fecal coliform trends across the entire Murrells Inlet watershed.

Element C: Evaluation of Potential Fecal Coliform Sources

ELEMENT C: Evaluation of Potential Fecal Coliform Sources and Common Transport Mechanisms

An important first step in developing this watershed-based plan was to conduct a general assessment of the potential bacteria sources in Murrells Inlet. This assessment involved soliciting input from residents, to gain local knowledge about the community and past water quality concerns in the watershed. The steering committee also worked closely with the local water and sewer districts, SC DHEC and SC DNR Shellfish Program staff, and other technical experts to rely on their scientific understanding of Murrells Inlet and its natural processes, with a primary focus on concerns related to bacteria loads in tidal estuaries. **Appendix G** provides a summary of potential bacteria sources in Murrells Inlet that were identified by local stakeholders at a workshop hosted on November 14, 2012.

Identifying potential bacteria sources can be especially difficult because some sources can be localized such as a malfunctioning septic system, while other sources such as pet waste need to be managed in an ongoing basis and can potentially be a problem almost anywhere in the watershed. This element highlights potential bacteria sources that are common to watersheds like Murrells Inlet with an evaluation of the suspected extent of the source and locations of concern where known in Murrells Inlet. This element also discusses common transport pathways by which bacteria are entering the estuary and persisting in the environment.

Figure C-1 *Bacteria source identification mapping exercise with local stakeholders. (Photo courtesy of Daniel Newquist, Waccamaw Regional COG)*

Potential Sources of Bacteria

Residential Septic Systems- Although most residents and businesses within the Murrells Inlet watershed are connected to the centralized sewer system, there are still a few areas that rely on septic systems for wastewater disposal. While the vast majority of existing septic systems are currently functioning properly, they do require long-term maintenance and regular inspections. Ideally these areas will eventually be connected to the sewer system. In the meantime targeted education should be a priority for homeowners relying on septic systems.

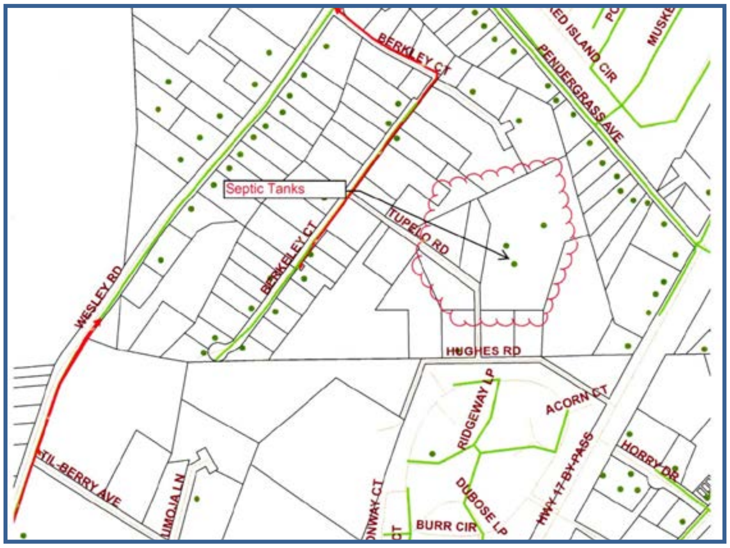
Below is a list of areas relying on septic systems located within the service areas of Georgetown County WSD and Grand Strand WSA:

Georgetown County WSD:

- *Wagon Wheel Mobile Home Park:* Located on the west side of US Highway 17 Bypass near Wesley Road, this mobile home park has approximately 60 units relying on septic systems.

- *Melton Avenue:* Located on the east side of US Highway 17 Business near the Murrells Inlet waterfront. There are only five residences on this street relying on septic systems; however, given the proximity to the Murrells Inlet waterfront close inspection of these systems is strongly recommended.

➢ *Tupelo Road:* Located off of Berkeley Ct. near Wesley Rd on the southwestern end of the watershed. There are three residences on this street that are relying on septic systems.



Grand Strand WSA:

➢ *Waterford Oaks:* Located off of Atlantic Ave just west of the Murrells Inlet shoreline. Waterford Oaks is a mobile home residential community accommodating both seasonal and long-term residents. There are approximately 150 individual dwellings within the development. Initial microbial source tracking monitoring conducted by Horry County Stormwater Department has not indicated that there are any bacteria contributions from septic systems in this community. Given the number of residences relying on septic systems and the close proximity to impaired portions of Murrells Inlet, it is imperative that these systems are regularly inspected and a contingency plan is in place in case there are septic system malfunctions in the future.

- *Pirate's Cove:* Located off of Atlantic Ave and Elizabeth Drive just west of the Murrells Inlet shoreline. Pirate's Cove is a long-term residential community on a tidally-influenced pond. Initial water quality monitoring conducted by Horry County Stormwater Department has not indicated that there are any bacteria contributions from septic systems in this community. Given the number of residences relying on septic systems and the close proximity to impaired portions of Murrells Inlet it is imperative that these systems are regularly inspected and a contingency plan is in place in case there are septic system malfunctions in the future.

Sewer Infrastructure- Centralized sewer systems consist of several components including gravity and forcemain sewer lines along with a series of pump stations that create an infrastructure network extending for several miles away from the ultimate wastewater treatment facility. The Grand Strand Water and Sewer Authority provides sewer service to the Horry County portions of the Murrells Inlet watershed. Meanwhile Georgetown County Water and Sewer District provides service to the Georgetown County areas of the watershed. Both agencies operate several wastewater treatment plants providing reliable utility services to thousands of customers. They each have documented records of environmental compliance throughout their respective agency histories as well. There are situations when a large storm such as a hurricane, an extended power outage, or some other type of an emergency situation can cause infrastructure issues resulting in sanitary sewer overflows (SSOs). Given the low-lying topography of Murrells Inlet, most of the pump stations are located near tributary creeks, which would be a direct pathway to the estuary in the event of a SSO. SC DHEC maintains a database of SSO incidents on their website at:

http://www.scdhec.gov/environment/water/wpc_sso.htm#ww_overflows

Figures C-2 and C-3: *Examples of pump stations in Murrells Inlet. The pump station on the left is located near the Point Drive Canal volunteer monitoring station and the one on the right is located near the BHR volunteer monitoring station (Photos courtesy of Dan Newquist, Waccamaw Regional COG and Dr. Dan Hitchcock, Clemson University).*

Sewer service customers also have responsibility for following proper guidance on disposing wastewater into the sanitary sewer system. In particular, problems can occur when grease is disposed of in the sewer system. Fats, oils, and grease (FOGs) can cause problems within a sewer system as they have a tendency to block sewer lines potentially leading to backup occurrences. Problems with improper FOG disposal is more common with restaurant establishments, but can also occur at single-family residences as well. Educational materials explaining the need to properly address grease management issues have been produced by Clemson University's Carolina Clear program. One of the action items recommended in **Element J** is to distribute these materials to local restaurants and vacation renters, possibly in cooperation with the SC DHEC Food Service Inspection program.

On the residential customer side, both sewer districts noted that homeowners occasionally remove the sewer clean out caps as a means of quickly draining ponded stormwater from their yards during large storm events. This causes excess stormwater to enter the sewer system, which increases the risk of overburdening nearby pump stations which are only designed to handle wastewater flow rates typical of households and businesses. Targeted homeowner outreach is necessary to eliminate this practice and is discussed further in **Element J**.

Pet Waste- One of the most preventable sources of bacteria where individuals can make a direct impact on water quality is the proper disposal of pet waste. If pet waste is not removed, it can eventually wash into the nearest storm sewer, creek or drainage ditch and then flow towards the inlet. Warm blooded animal feces contain millions of fecal coliform bacteria and if removal is not made a community priority then it can become a significant contributor to fecal coliform impairments in Murrells Inlet.

Monitoring data collected as part of Horry County's microbial source tracking study (further discussed in **Element D**) have indicated that canine waste is a contributor of fecal coliform in the northern portion of the Murrells Inlet watershed. As a community, Murrells Inlet has a number of residential neighborhoods as well as several waterfront areas that attract vacation renters. The Murrells Inlet area is also a major outdoor recreational destination with several parks, walkways, and boat landings making it a popular place for people to bring their pets. Educating both local residents and visitors on the importance of removing pet waste and the direct linkage to the environmental sensitivities of the local estuary and shellfish habitat areas is critical. Georgetown County has been proactively addressing this issue by installing numerous pet waste disposal stations and through other public outreach initiatives. In 2012, over 11,000 pet waste bags were used at six pet waste station locations. As this will be an ongoing management need, additional public education ideas and strategies to address pet waste are explored in **Element J** of this plan.

Figures C-4 and C-5: *While efforts have been made to educate the public on the need to pick up pet waste, problems continue to be observed even near shoreline areas. Proper pet waste disposal needs to continue to be a priority in the Murrells Inlet community. (Photos courtesy of Murrells Inlet 2020)*

Wildlife and Bird Populations- The Murrells Inlet area possesses some of the region's most beautiful coastal natural habitats. Huntington Beach State Park and Brookgreen Gardens span more than two thousand acres on the south end of the Murrells Inlet watershed, providing critical habitat for an incredible diversity of wildlife species. Bird photographers and nature enthusiasts from across the country come to Murrells Inlet to observe large populations of resident and migrating bird species such as wood storks, ibises, herons, egrets, pelicans, gulls, ducks, shorebirds and even recent sightings of roseate spoonbills. The bird and mammal populations that once resided in areas that are now developed, concentrate in these undeveloped portions of the watershed. Wildlife has always contributed significantly to the natural background levels of bacteria present in the estuary. The regulator's and watershed manager's dilemma is how to effectively manage water quality in a balanced way for the benefit of all species, and not just one (e.g., eastern oyster) if by doing so proves to be detrimental to the others.

Figure C-6: *There are extensive forested areas suitable for wildlife in the watershed, particularly in the southern portions in Georgetown County. (Photo courtesy of Daniel Newquist, Waccamaw Regional COG)*

An important yet challenging aspect of regulating and managing water quality in Murrells Inlet is to accurately account for the bacteria contributions from wildlife species populations that are known to inhabit Murrells Inlet. A chart with estimated average bacteria loads for various animal species based off of information provided by NOAA's Nutrient and Coliform Loading Project is provided in **Appendix D**. By doing so, watershed managers are able to distinguish anthropogenic bacteria sources (e.g those associated with human activities) from wildlife sources where the management strategies are limited. One of the few management activities to minimize wildlife sources is to discourage feeding waterfowl and being careful not to leave pet food outdoors which can attract small mammals such as raccoons and opossums. Many strategies can also be used to discourage birds from roosting on docks and platforms adjacent to the estuary however the effectiveness of this approach is less known.

Table C-1 is a list of subwatersheds that are predominately open space areas well suited as wildlife habitat. These thirteen subwatersheds account for 1,969.75 acres or 31.2% of the 6,322.50 acres of land area that drain into the Murrells Inlet estuary. The Bike Bridge subwatershed (507.98 acres) is a transitional area between the primarily undeveloped portions of Murrells Inlet and the urbanized neighborhoods between Business Rte 17 and Bypass Rte 17. It is also worth noting that waterfowl often inhabit shoreline areas along docks and ponds in the more densely urbanized portions of Murrells Inlet.

Figures C-7 and C-8: *The Murrells Inlet estuary is populated by a wide variety of resident and migratory bird species including pelicans, wood storks, roseate spoonbills, among many others. (Photos courtesy of Gary Weinreich, Murrells Inlet Volunteer Monitoring Program)*

There are also large populations of opossums, raccoons, and other small mammals that are common to urban/suburban settings. These species can cause nuisances by foraging through trash bins, dumpsters, or around homes. Even coyote have been regularly observed in developed sections of the watershed. A periodic wildlife species inventory, which is recommended in **Element K: Water Quality Monitoring Strategic Plan**, would assist water resource managers in accurately estimating potential bacteria sources from wildlife or from domesticated animals such as dogs and feral cat colonies. It should also be noted that there are a few small farms within the watershed which keep horses, livestock, and other animals. Measures such as proper fencing or a vegetated buffer adjacent to nearby ditches and creeks would help to minimize bacteria loadings and potential impacts on water quality in the inlet.

Table C-1 Subwatersheds with Significant Land Areas Suitable for Wildlife Populations			
Basin Name	**Acres**	**Basin Name**	**Acres**
Brookgreen SW	394.50	*Brookgreen S*	100.93
HBSP Main Beach	323.77	*Brookgreen SE*	83.80
Brookgreen NW	304.58	*Oyster Landing*	56.53
Huntington Marsh	182.62	*HBSP Ed Center*	27.23
HBSP North Beach	171.34	*Brookgreen N1*	20.21
HBSP Causeway	151.75	*Brookgreen NW1*	19.34
Brookgreen N	133.15	**TOTAL**	**1969.75 acres**
Source: Based off of subwatershed delineations produced by Earthworks Group, LLC			

Legacy Sources- Murrells Inlet, like many other communities along the South Carolina coast, has undergone significant change over the past few decades. Development has altered the landscape in many areas of the watershed, with the exception of land managed by Huntington Beach State Park and Brookgreen Gardens. Some of the residential neighborhoods in Murrells Inlet were once utilized for agricultural purposes. Among the former uses include a goat farm and a chicken processing plant. Knowing that these activities occurred for long-periods of time, it is worth further investigating whether these former land uses, in addition to others, may possibly be legacy sources of bacteria. Investing monitoring resources to investigate the influence of these sites on bacteria levels is a recommendation outlined in **Element K, Water Quality Monitoring Strategic Plan.** If a study indicates that no impact exists, then watershed managers know that they can shift their efforts to other known sources.

Common Bacteria Transport Pathways

Stormwater Runoff- During a precipitation event, water flows across the ground surface and ultimately infiltrates into the groundwater system or is transported via runoff into nearby ditches and streams, eventually draining into the closest main waterbody. Most conventional storm sewer systems do not have treatment mechanisms, therefore runoff carrying debris, sediment, bacteria, or other contaminants is discharged into the aquatic environment, potentially affecting water quality. A common problem that growing communities face is managing runoff rates and contaminant loads as development increases. Hard surfaces such as buildings and roads are impervious to groundwater infiltration, often leading to higher surface runoff rates and volumes.

Stormwater runoff can affect bacteria levels in the Murrells Inlet estuary in differing ways. First, stormwater runoff is the primary transport mechanism for any non-point source of bacteria. When stormwater runoff reaches the inlet in greater volumes and at a faster rate, a lower percentage of bacteria that exists on the land can be retained at the point of origin prior to reaching the main channel in Murrells Inlet. Another factor that may indirectly influence bacteria levels is the change in salinity balance in the estuary due to the increase of freshwater inputs. Bacteria do not survive as long in high salinity waters.

New technologies and strategies have emerged such as Low Impact Development (LID), which are designed to mimic predevelopment hydrology by retaining and treating stormwater generated onsite following a precipitation event. A few examples of LID techniques which have been implemented in Murrells Inlet are highlighted in **Element H: Watershed Management Measures.** Structural stormwater management practices such as LID are one of the main recommendations highlighted in **Element H**.

Figure C-9 *Conventional storm drain which directs runoff untreated into the nearest waterbody (Photo courtesy of Dr. Dan Hitchcock, Clemson University)*

Figure C-10 *An example of an LID practice which helps retain stormwater onsite while also providing filtration and pollutant removal benefits. (Photo courtesy of US EPA)*

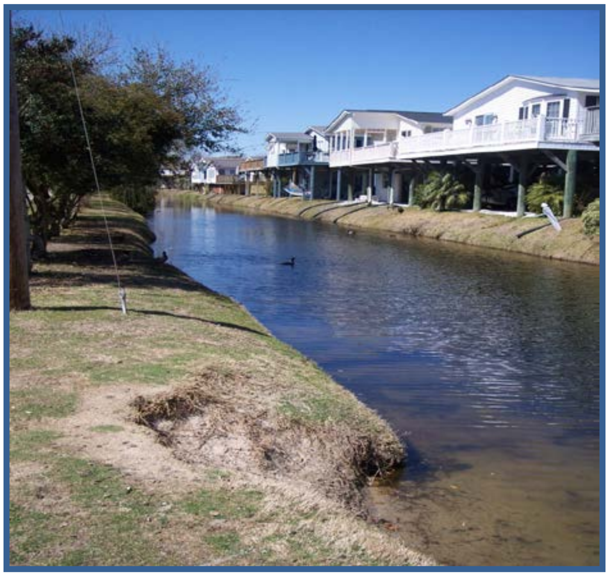
Land Use Change- A secondary impact resulting from urbanization over time is the associated increase in impervious coverage in the watershed. As discussed above, development often changes the natural hydrology in the landscape requiring investments in stormwater infrastructure. To assess changes in land use properties over time, National Aerial Photography Program (NAPP) Color Infrared aerial photographs from 1994 were compared to natural color aerial photography flown in 2012. Land use change was quantified by assessing the change in Curve Numbers.

Current land use Curve Number characteristics provided a baseline for comparative purposes against the change in land use between 1994 and 2012. The United States Department of Agriculture (USDA) Natural Resources Conservation Service (SCS) developed the Curve Number method to help determine rainfall runoff rates during storm events. Curve Numbers are calculated by evaluating the hydrologic classification given to soil groups in conjunction with the type of land use present. For example, soils with high permeability (Type A) that can retain more water during rainfall events, if found in a forested area with no impervious surfaces, would have a very low Curve Number value (e.g. 30) A 30 value means that the landscape will retain and release water from the watershed slowly. Comparatively, an area of Medium Density Residential (1/4 acre lots) land use with poorly drained soils (Type D) would have a much higher Curve Number Value (e.g. 87). Those areas would more rapidly release water if there was a lack of onsite retention. Finally, fully impervious surfaces such as asphalt parking lots, driveways, and roads are designated with the highest Curve Number (e.g. 98). These areas exhibit the highest runoff rates following rain events because water immediately begins flowing across them with no infiltration.

Exhibit C-1 displays the rate of Curve Number change for each delineated subwatershed within Murrells Inlet. **Appendix G** provides a list and a description of all of the soil types that are found in the Murrells Inlet watershed.

Drainage Ditches- As one of the primary mechanisms for stormwater runoff and sediment transport, drainage ditches have the potential to be a main conduit of bacteria loads**.** Our steering committee consulted with watershed managers in Bluffton, SC, who have undertaken a similar watershed planning project in the May River watershed. One of their main priorities has been focused on stormwater volume reduction and drainage ditch maintenance. Their watershed plan has also acknowledged the tendency of small mammals, such as raccoons and opossum to utilize drainage ditches as a freshwater source and habitat area. Similar observations have been made in the Murrells Inlet area by residents and county stormwater staff.

There are ways to minimize erosion and to reduce bacteria concentrations in the drainage ditch network. Drainage ditches can be designed to decrease stormwater flow rates and increase retention times. There are also opportunities in drainage ditches to install stormwater filtration devices to remove bacteria prior to entering the inlet. One of the major products of this watershed plan is the extensive mapping of the drainage network in each of the 51 subwatersheds within Murrells Inlet. This detailed mapping provides an inventory of the creeks, ditches, retention ponds, culverts, and catch basins that collect and convey stormwater runoff. The mapping illustrates the conveyance of hydrology within each subbasin drainage area to a specific discharge point into the inlet. The subwatershed maps were utilized in identifying possible locations within Murrells Inlet to invest in structural BMPs to minimize bacteria contributions from ditches and other key components of the stormwater infrastructure network. The list of specific BMP recommendations is included in **Element H.**



Figures C-11 and C-12: *The stormwater infrastructure system within the watershed consists of an extensive network of canals, ditches, ponds, pipes, and outfalls. In some cases, residents have attempted to address localized drainage issues by constructing small scale ditches. These practices can exacerbate erosion problems and potentially affect drainage patterns in downstream areas nearby. (Photos Courtesy of Dan Newquist, Waccamaw Regional COG and Dr. Dan Hitchcock, Clemson University)*

Sedimentation- An issue closely related to stormwater runoff is the transport and settling of sediments into creekbeds and shellfish habitat areas. Soil erosion is a natural process that occurs in every watershed to varying extents. Problems arise however if erosion occurs to a degree that negatively impacts aquatic habitat or drastically alters the hydrodynamic characteristics of a waterbody. Several stakeholders have noticed numerous changes since the construction of the jetty in 1980. The jetty structure which provides safe passageway for vessels entering the main channel of Murrells Inlet has altered the tidal flow dynamics and ultimately the soil deposition patterns in the watershed. Concerns regarding sedimentation resulting from inadequate stabilization during roadway construction and follow up maintenance have also been observed.

In Murrells Inlet, excessive sedimentation can affect the habitat quality of oyster populations. It has been observed by local residents that parts of Murrells Inlet, such as Parsonage Creek, Main Creek, and Garden City Canal have become shallower due to a significant build up of sediment. These changes have become even more pronounced in both the northern and southern end upper reaches of the watershed. The end result is that over time these areas experience diminished tidal flushing, changing the salinity balance, and possibly affecting shellfish habitat.

PREPARED BY:	MAP TITLE:	PROJECT TITLE:	DATE:	PREPARED FOR:	SCALE:	PROJECT LOCATION:	Legend
EARTHWORKS planning and design consultants 11655 HIGHWAY 707 MURRELLS INLET, SC 29576 phone - 843-651-7900 fax - 843-651-7903 www.earthworksgroup.com	MURRELLS INLET WATERSHED INVENTORY Exhibit C-1 Subwatershed Analysis	MURRELLS INLET WATERSHED MANAGEMENT PLAN	07/11/2013 TEG PN: 121108.000:E AUTHOR: SWILLIAMS	MURRELLS INLET 2020 4124 Hwy. 17 Business P.O. Box 1357 Murrells Inlet, SC 29576	1:36,000 0 1,500 3,000 FEET	MURRELLS INLET GEORGETOWN COUNTY SOUTH CAROLINA	Community Input SCDHEC Monitoring Volunteer Monitoring Impaired: No Impaired: Yes SCDHEC Commercial Beds Sub Watersheds Approx. Hydrology

As discussed in more detail in **Element D,** bacteria are known to bind to sediment particles and can survive and even multiply in an aquatic environment over an extended period of time. Bacteria levels can increase when sediments are disturbed and become resuspended in the water column. The fine sediments are stirred from the shallow creeks by rainfall runoff, high winds, and boat traffic at low tides. The resuspended sediments, especially those less than 5 microns in diameter, carry attached bacteria into the inlet. Because of their very small diameter, they do not readily settle and remain in the water column for extended periods. (Anderson and Greoski 2010).

Figures C-13: *Substantial sedimentation has been observed in several upstream creeks and tributaries, as evidenced in this segment of Point Dr. Canal. (Photo courtesy of Dr. Dan Hitchcock, Clemson University)*

Boating- Murrells Inlet is one of the most popular recreational boating destinations along the Grand Strand and in all of South Carolina. Most of the boating activity in Murrells Inlet is limited to daytime use, with infrequent transient boat traffic. As a result, improper holding tank discharges in Murrells Inlet has not been an issue. Initial microbial source tracking data collected by Horry County Stormwater Department has not shown significant evidence of human sources of bacteria in the main channel of the inlet. However, since the potential for illicit discharge exists and incidents have occurred in the past it is important to make boaters aware of the regulations pertaining to holding tank discharges and provide other boaters the appropriate contact information to notify the Coast Guard or other relevant enforcement agencies if they suspect that an illicit discharge has occurred.

One of the consensus findings of the steering committee is the noticeable siltation that has occurred in Murrells Inlet in recent years. One cause of the sedimentation observed in Murrells Inlet is shoreline erosion resulting from excessive boat wakes. **Element I: Public Education and Outreach Resources** is structured to prioritize public awareness strategies to specific target groups, one of them being recreational boaters. Making boat owners mindful of “No Wake Zones” is important not only for public safety and private property reasons but also to ensure that the sensitive marsh and shellfish habitats are not disturbed. It may be worth examining the appropriateness of expanding “No Wake Zones” in areas known to be experiencing pronounced shoreline erosion and siltation. The Murrells Inlet area has several public boat landings. Due to the high popularity and regular use of these amenities, they are ideal locations for interpretive signs or other public awareness tools.

Figure C-14: *Murrells Inlet is one of the most popular boating destinations in the state. Boat landings can serve as good locations for public education signage regarding water quality, shellfish habitat and boating related issues such as the impacts of boat wakes. (Photo courtesy of SC DNR)*

Summary Evaluation

Following extensive discussions on potential sources of bacteria that exist in Murrells Inlet, the project steering committee has come to the following conclusions regarding the relative contributions, by rank order, of each source.

1. **Wildlife and Waterfowl:** Based on an assessment of available investigatory monitoring data including the Murrells Inlet Volunteer Monitoring program, Horry County microbial source tracking study, and the Georgetown County upstream monitoring initiative it appears that wildlife and waterfowl is the largest contributing source of bacteria in the Murrells Inlet watershed. Other visual observations such as animal tracks in creek beds, road kill frequencies, and other wildlife sightings support this finding. The estuary supports habitat for numerous waterfowl populations which maintain a noticeable presence along the shoreline throughout Murrells Inlet.

2. **Pet Waste:** As discussed earlier in this element, pet waste is recognized as a community-wide pollution concern in Murrells Inlet and is suspected to be the second largest source of bacteria. As noted, indications are that the pet waste stations are being used and are helping to eliminate significant bacteria loads from the environment. A management challenge is encouraging private landowners from picking up pet waste on their own properties.

3. **Septic Systems:** The available monitoring data indicates that the existing septic systems in Murrells Inlet are working properly and show no evidence of contributing bacteria into the estuary. However, septic systems remain a potential source and the steering committee views it as an important preventative management priority.

4. **Sewer Infrastructure:** Similarly, little evidence has indicated that the existing sewer line and pump station network is a significant source of bacteria in Murrells Inlet. A few stakeholders have expressed concerns regarding the location of several pump stations immediately adjacent to tidal creeks and tributaries and occasional odor has also been observed. Ongoing coordination with the water and sewer districts will be encouraged. One recommendation is to conduct a microbial source tracking study of the pump station inventory to assess whether human bacteria sources from the sewer network are contaminating adjacent creeks or sediments.

5. **Hobby Farms:** There are a few properties with horses and livestock in Murrells Inlet. They are not suspected to be significant sources, however local watershed managers will work with the property owners to encourage appropriate management practices such as fencing or establishing vegetative buffers along nearby shorelines.

6. **Illicit Boat Discharges:** While illicit boat discharges are a potential bacteria source, little evidence suggests that it is currently a problem. The project steering committee views it as a preventative management issue and will continue to support public outreach efforts to boaters and work with law enforcement officials to ensure that incidents are avoided in the future.

Other conclusions that the steering committee made during the bacteria source assessment were as follows:

- From a management perspective, it was agreed that addressing the listed sources on a subwatershed scale is most effective. Obviously, contributions from septic systems will be limited to specific locations within the community. Also the relative contributions of wildlife and pet waste will vary from one area of the watershed to another.

- As discussed at length in this element, an equally important aspect in managing bacteria sources involves addressing concerns related to the transport mechanisms, particularly stormwater runoff, the drainage ditch network, and sedimentation. The steering committee acknowledges that while it is not possible nor ethical to eliminate wildlife as a source, it is possible to reduce the ultimate fate and transport of wildlife sources through innovative stormwater management strategies.

The next element provides a more technical analysis of monitoring data collected by SC DHEC and the Murrells Inlet Volunteer Monitoring Program. This element serves as the principal baseline assessment that identifies bacteria trends over time and the influence of wet weather conditions on fecal coliform levels. **Element D** also provides a geographic perspective of areas that have historically shown higher levels of fecal coliform.

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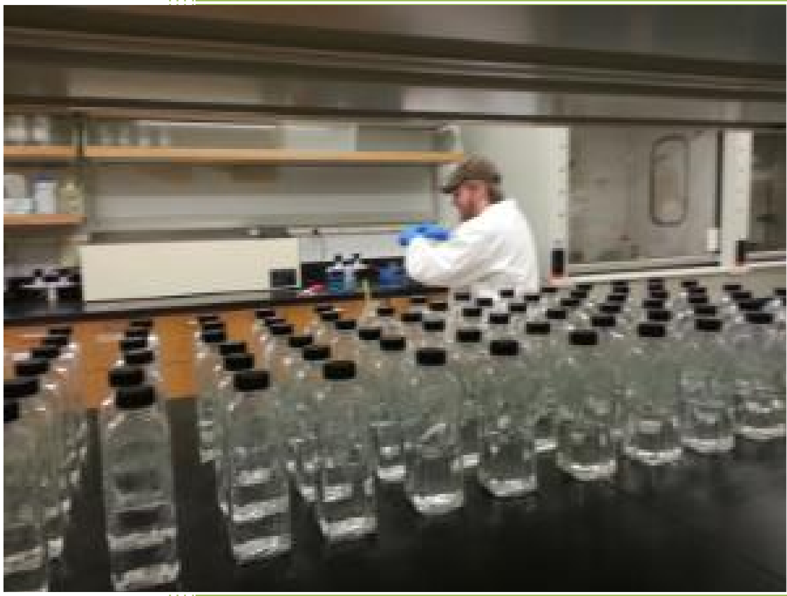
Element D: Fecal Coliform Trend Analysis



ELEMENT D: Fecal Coliform Trend Analysis

One of the primary means of evaluating the environmental health of an ecosystem is through ongoing research and monitoring. As outlined in **Element B**, the State of South Carolina has collected water quality samples as part of their management decision-making framework since the early 1960s. In addition, other entities such as SC DNR, NOAA, Coastal Carolina University, and University of South Carolina have conducted numerous studies and research projects to increase the scientific understanding of coastal estuarine systems such as Murrells Inlet. More recently, Georgetown and Horry Counties have partnered with Murrells Inlet 2020 and Coastal Carolina University to initiate a volunteer monitoring program at eight sites throughout Murrells Inlet. Of the eight sites, two are located on tidal creeks, three are on small freshwater impoundments, and three are on small, free-flowing, freshwater creeks.

The monitoring information provided by each of these entities has implications on shellfish harvesting activities and is essential to protecting water quality in Murrells Inlet. As part of an adaptive management approach, long-term monitoring programs enable local watershed managers to optimize resources and employ targeted interventions. The monitoring data can and should guide decisions regarding appropriate management strategies to pursue in the watershed.

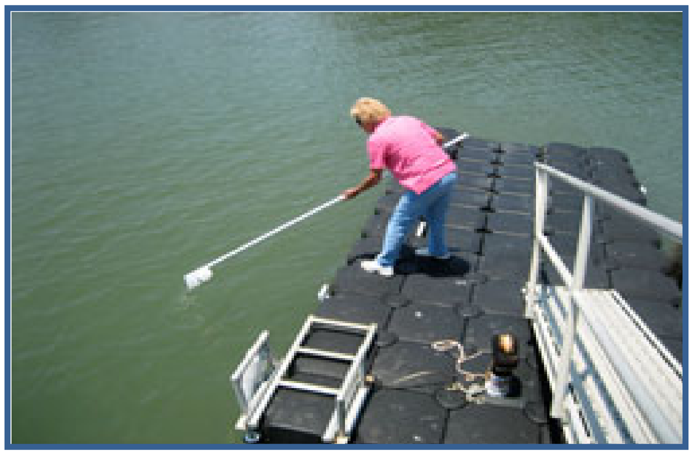


Figure D-1 *Volunteer collecting a sample as part of the Murrells Inlet Volunteer Monitoring Program. (Photo courtesy of Coastal Carolina University)*

This element is an in-depth analysis of the fecal coliform trends as reported by the SC DHEC Shellfish Program since the early 1990s. Other observations such as precipitation data collected by the National Weather Service at Brookgreen Gardens and supplemental monitoring data from the Murrells Inlet Volunteer Monitoring Program are summarized and discussed. Faculty and staff from Coastal Carolina University's Waccamaw Watershed Academy conducted the data analysis. This baseline assessment of historical water quality trends and current conditions in Murrells Inlet is the primary basis for the recommendations outlined in the remainder of this watershed-based plan.

Fecal Coliform Data Analysis Plan

The purpose of conducting a thorough review of the historical monitoring data was to answer the following key questions, each of which will be discussed in more detail later in the element:

- Which monitoring sites have had persistently elevated concentrations of fecal bacteria?
- Have the fecal coliform levels at each monitoring site increased or decreased over time?
- Are fecal coliform concentrations higher under wet or dry weather conditions?
- What factors could be influencing the time trends in fecal coliform concentrations?

The primary sources of data analyzed in this baseline assessment were the following:

- SC DHEC Shellfish Program: Fecal Coliform Monitoring Data, 1967-2012. Note that there SC DHEC utilized a new method for collecting fecal coliform data beginning in 1992.
- SC DHEC Shellfish Program: Shellfish Management Area 04, Annual Update Reports 1992-2013
- 2005 Murrells Inlet Fecal Coliform TMDL
- Murrells Inlet Volunteer Monitoring Program: E. Coli and Total Coliform Data, 2008-Present
- National Weather Service, Brookgreen Gardens Rain Gauge, Precipitation from 1958 to present.
- 2013 Horry County Microbial Source Tracking Study
- 2013 Georgetown County Upstream Monitoring Initiative

Summary of Regulatory Status Trends in Murrells Inlet

This next section reviews the regulatory status of each of the SC DHEC Shellfish monitoring stations since 1992. Both the geometric mean standard of 14MPN/100ml and the 90^{th} percentile standard of 43MPN/100ml are analyzed. This provides a long-term perspective of which monitoring sites have regularly exceeded the standards, which sites have always met the standard, and which sites only periodically exceed the standards. As a note, as indicated in **Figure D-2** below the number of monitoring sites sampled by SC DHEC does vary periodically due to shifts in monitoring priorities and in some cases reductions in available program resources.

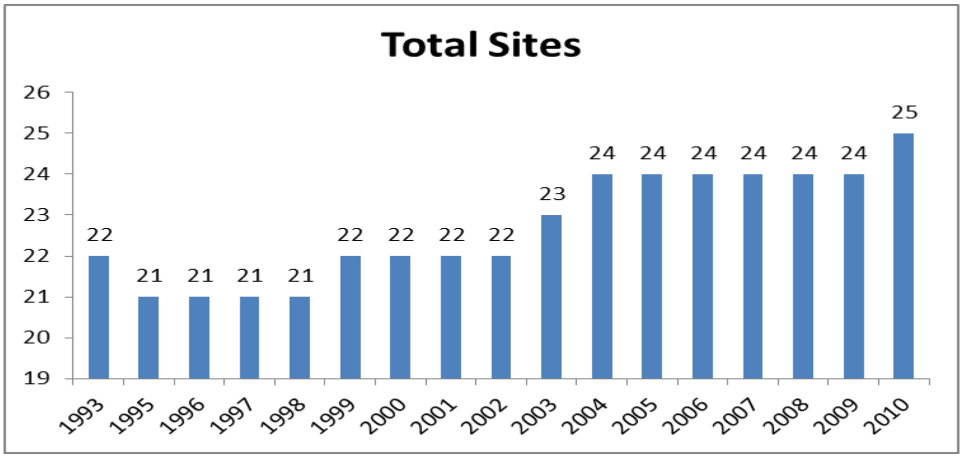


Figure D-2 *Number of monitoring sites sampled by DHEC since 1993.*

Table D-1 displays the regulatory trends for the geometric mean standard of 14MPN/100ml over the last twenty years using a three- year running statistic as presented in the annual shellfish reports. As indicated, the majority of the monitoring sites have consistently met the geometric mean standard. Sites 04-01(Main Creek at Atlantic Avenue Bridge), 04-08(Parsonage Creek at Nance's Dock), and 04-16(Parsonage Creek at Chicken Farm Ditch) have experienced fecal coliform levels above the 14MPN/ 100ml geometric mean standard on a regular basis for the past 20 years. Over this same time period monitoring site 04-26,(Garden City Canal at the "Old Boat Wreck"), 04-02 (Main Creek at Mickey Spillane's Home) and 04-27 (Main Creek Opposite Entrance to Mt. Gilead Canal) has met the geometric mean standard the majority of the time, but recently has exceeded the 14MPN/100ml threshold.

Table D-2 is an overview of the regulatory trends for the est. 90th percentile fecal coliform standard of 43MPN/ 100 ml in Murrells over the last twenty years using a three-year running statistic as presented in the annual shellfish reports. The est. 90th percentile standard is the more difficult threshold to meet, due in large part to the high temporal variability observed in fecal coliform levels. In coastal estuarine environments such as Murrells Inlet, fecal coliform concentrations are highly influenced by rain events, salinity levels, wind, tidal currents and stage, sunlight exposure, and other environmental factors, which can lead to drastic fluctuations in fecal coliform levels. The est. 90th percentile standard is a conservative limit designed to safeguard the general public from illnesses caused by consumption of raw shellfish products. Ultimately it is a difficult standard to meet but remains the targeted goal in this plan, as it is necessary in order to maximize the Approved acreage available for shellfish harvesting.

Table D-1: Geometric Mean Trends by Monitoring Site

Sites	1992-1994	1994-1996	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010	2009-2011	2010-2012	%Over
1	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
1A	O	O	O	O	O	O	O	O	*Monitoring discontinued beyond this date*										100%
2	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	O	O	O	17%
3	U	U	U	U	U	U	U	U	*Monitoring discontinued beyond this date*										0%
03A	*Monitoring not initiated until this date*								U	U	U	U	U	U	U	U	U	U	0%
03B	*Monitoring not initiated until this date*								U	U	U	U	U	U	U	U	U	U	0%
4	U	U	U	U	U	U	U	U	U	U	*Monitoring discontinued beyond this date*								0%
04A	*Monitoring not initiated until this date*									U	U	U	U	U	U	U	U	U	0%
04B	*Monitoring not initiated until this date*										U	U	U	U	U	U	U	U	0%
04C	*Monitoring not initiated until this date*										U	U	U	U	U	U	U	U	0%
5	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
6	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	O	O	U	11%
7	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
8	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
08A	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
16	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
17	O	U	U	U	U	U	U	U	*Monitoring discontinued beyond this date*										13%
17A	*Monitoring not initiated until this date*								U	U	U	U	U	U	U	U	U	U	0%
18	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
22	U	*Monitoring discontinued beyond this date*																	0%
23	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
24	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
25	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
26	U	U	U	U	U	U	U	O	O	O	O	O	U	U	U	O	O	O	44%
27	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	O	O	O	17%
28	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	O	U	U	6%
29	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
30	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
31	*Monitoring not initiated until this date*					U	U	U	U	U	U	U	U	U	U	U	U	U	0%
32	*Monitoring not initiated until this date*																U	U	0%
%Year	23%	19%	19%	19%	19%	18%	18%	23%	18%	17%	17%	17%	13%	13%	13%	33%	28%	24%	
	NOTES:		O= Over Geomean Standard of 14 MPN/100ml									U= Under Geomean Standard of 14MPN/100ml							

Table D-2: 90th Percentile Trends by Monitoring Site

Sites	1992-1994	1994-1996	1995-1997	1996-1998	1997-1999	1998-2000	1999-2001	2000-2002	2001-2003	2002-2004	2003-2005	2004-2006	2005-2007	2006-2008	2007-2009	2008-2010	2009-2011	2010-2012	%Over
1	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
1A	O	O	O	O	O	O	O	O	*Monitoring discontinued beyond this date*										100%
2	O	U	U	O	O	O	U	O	O	O	O	O	O	O	O	O	O	O	83%
3	U	U	U	U	U	U	U	U	*Monitoring discontinued beyond this date*										0%
03A	*Monitoring not initiated until this date*								O	O	U	U	U	U	U	U	U	U	20%
03B	*Monitoring not initiated until this date*								O	O	U	U	U	U	U	U	U	U	20%
4	U	U	U	U	U	U	U	U	U	O	*Monitoring discontinued beyond this date*								10%
04A	*Monitoring not initiated until this date*									U	O	U	U	U	U	U	U	O	22%
04B	*Monitoring not initiated until this date*									U	U	U	U	U	U	U	U	U	0%
04C	*Monitoring not initiated until this date*									U	U	U	U	U	U	U	U	U	0%
5	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
6	O	U	U	U	U	O	O	O	O	O	O	O	U	U	O	O	O	O	67%
7	O	U	U	U	U	U	U	U	U	U	U	U	U	O	O	O	O	O	33%
8	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
08A	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
16	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	O	100%
17	O	U	O	O	O	U	U	O	*Monitoring discontinued beyond this date*										63%
17A	*Monitoring not initiated until this date*								O	O	U	O	U	O	U	U	O	O	60%
18	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	O	O	U	11%
22	O	*Monitoring discontinued beyond this date*																	100%
23	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
24	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
25	U	U	U	U	U	U	U	U	U	O	O	U	U	U	U	U	O	U	17%
26	O	U	U	U	O	O	O	O	O	O	O	O	O	O	O	O	O	O	83%
27	O	U	O	U	O	O	O	O	O	O	O	O	U	O	O	O	O	O	83%
28	O	U	U	U	U	U	U	U	O	O	O	U	U	U	U	O	O	O	39%
29	O	U	U	U	O	U	U	U	U	U	U	U	U	U	U	U	U	U	11%
30	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	0%
31	*Monitoring not initiated until this date*					U	U	U	U	O	O	U	U	U	U	O	O	O	38%
32	*Monitoring not initiated until this date*																U	U	0%
%Year	59%	19%	29%	29%	43%	36%	32%	41%	50%	61%	46%	33%	21%	33%	33%	46%	52%	48%	

NOTES: O= Over 90th Percentile Standard of 43MPN/100ml   U= Under 90th Percentile Standard of 43MPN/100ml

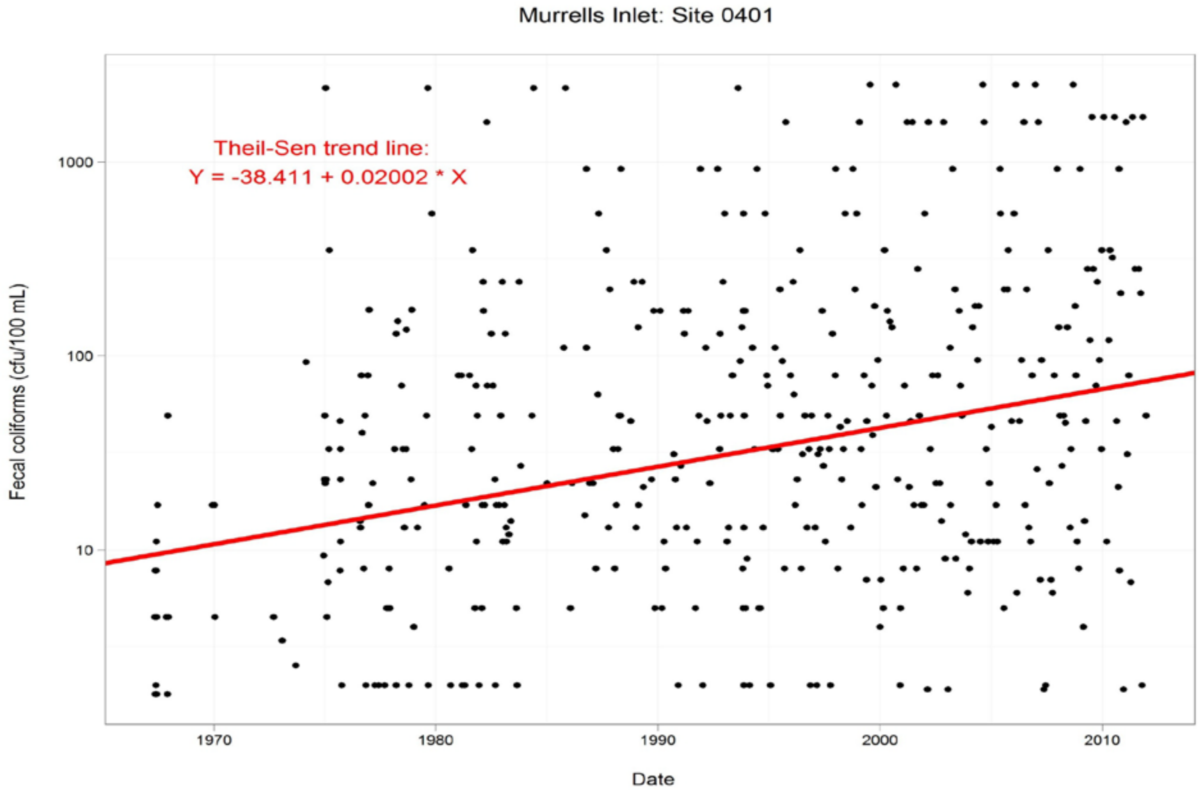


Figure D-3 *As indicated in this scatter plot of data from SC DHEC monitoring station 04-01, the variability in fecal coliform levels is quite noticeable, and can be influenced by rainfall, tide, wind and several other environmental factors. Statistical trend analysis is important in assessing the water quality trends over time in Murrells Inlet. (Graph produced by Dr. Susan Libes based on monitoring data from 1967- 2011)*

In addition to having a high frequency of contravening the geometric mean standard, monitoring sites 04-01, 04-08, and 04-16 also consistently exceed the est. 90th percentile standard throughout the period of analysis. **Element F, Targeted Subwatershed Load Reductions** further examines monitoring sites and adjacent subwatersheds that have been identified as priority areas for best management practice consideration. Due to the persistently high levels of fecal coliform, monitoring sites 04-01, 04-08, and 04-16 have been designated as Tier 1, or the highest priority sites for improvements. Other active monitoring sites that have exceeded the est. 90th percentile standard more than half of the years in this period of analysis include 04-02, 04-06, 04-17A (Southwest Corner of the Voyager View Marina Prohibited Zone in Parsonage Creek), 04-26, and 04-27. They have also been identified as priority sites in **Element F.**

Appendix D includes graphs for each monitoring station that display the fecal coliform three year running average trends (as used in the SC DHEC Shellfish Reports) over time since 1992 and their relation to both the geometric mean and the 90th percentile standard for fecal coliform. As discussed above, the tendency to exceed the 90th percentile standard is more common than exceeding the geometric mean water quality standard. Time trend graphs were also produced for each monitoring site and are also included in **Appendix D**.

HISTORIC RAIN DATA- BROOKGREEN GARDENS

It has been documented that fecal coliform levels are strongly influenced by the frequency of rainfall events within a watershed area. The primary rain gauge in the general vicinity of Murrells Inlet used by regulatory agencies including the National Weather Service and SC DHEC is located at Brookgreen Gardens. The precise location of this rain gauge is 33.519444"N and -79.091829"W, which is outside the watershed boundary of the Murrells Inlet estuary and approximately 1.5 miles from the nearest point on the inlet at the Huntington Beach State Park causeway.

One of the primary advantages of using the Brookgreen Gardens rainfall gauge is that rainfall has been consistently recorded in daily intervals at this site since the late 1950s making it a very reliable source of data. There are some disadvantages with using Brookgreen Gardens as a sole data source for precipitation and are mentioned below:

- Location of Brookgreen Gardens is outside of the Murrells Inlet watershed boundaries.
- There has been an increase in daily missed readings in recent years resulting in larger data gaps.
- The weather conditions in Murrells Inlet can vary significantly, especially during summer thunderstorm events. Having multiple reliable rain gauges would provide a more representative data set of rainfall patterns in Murrells Inlet.

Recommendations are outlined in **Element J: Water Quality Monitoring Strategic Plan** to establish additional rain gauge sites at other locations within Murrells Inlet, perhaps even through the Community Collaborative Rain Hail and Snow Network, a citizen reported program, commonly referred to as CocoRahs.

Having a firm understanding of the effect of rainfall on fecal coliform levels is critical to the management of shellfish harvesting activities. In the past, SC DHEC has managed shellfish harvesting areas utilizing the Conditionally Approved classification for some areas that did not meet the Approved classification. A Conditionally Approved area requires a site specific management plan typically related to closure criteria during wet weather periods. **Figure D-4** displays the annual rainfall precipitation data at Brookgreen Gardens dating back to 1958. According to SC DNR's State Climatology Office, the Coastal Plain portion of South Carolina normally receives a total of 50-52 inches of rain yearly. As the graph indicates, over the last decade the area has received below average rainfall. The implications on the relationship to fecal coliform levels are multifold and are explained later in this element.

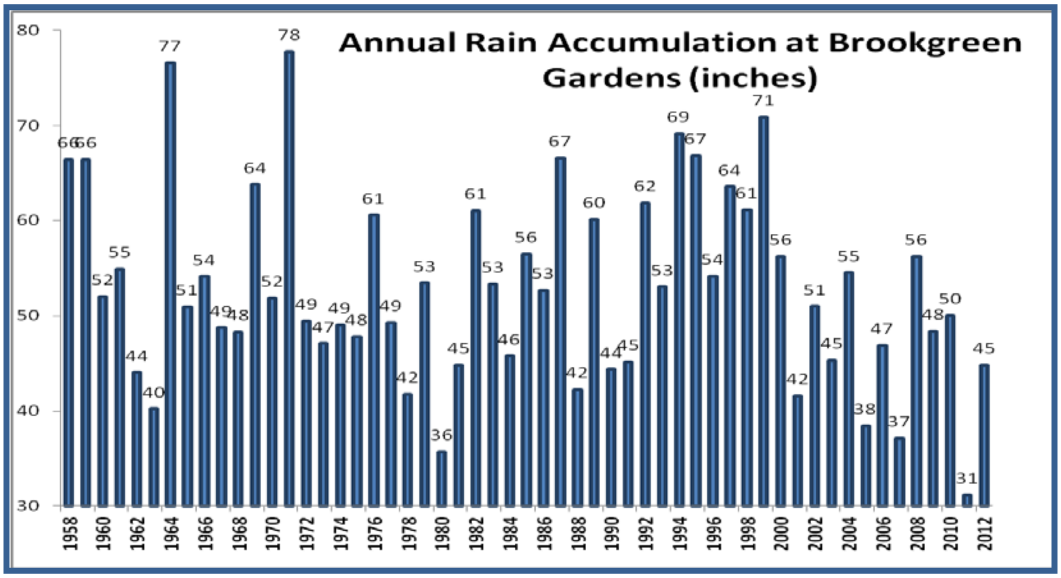


Figure D-4: *Annual Rainfall Totals at Brookgreen Gardens*

Figure D-5 displays the occurrence of significant rainfall events on an annual basis. In this baseline assessment, long-term trends at each monitoring site were analyzed based on the previous three days of wet (minimum total precipitation of 0.5”) or dry (no rainfall) weather conditions, which is a typical reference timeframe in stormwater regulatory practices.

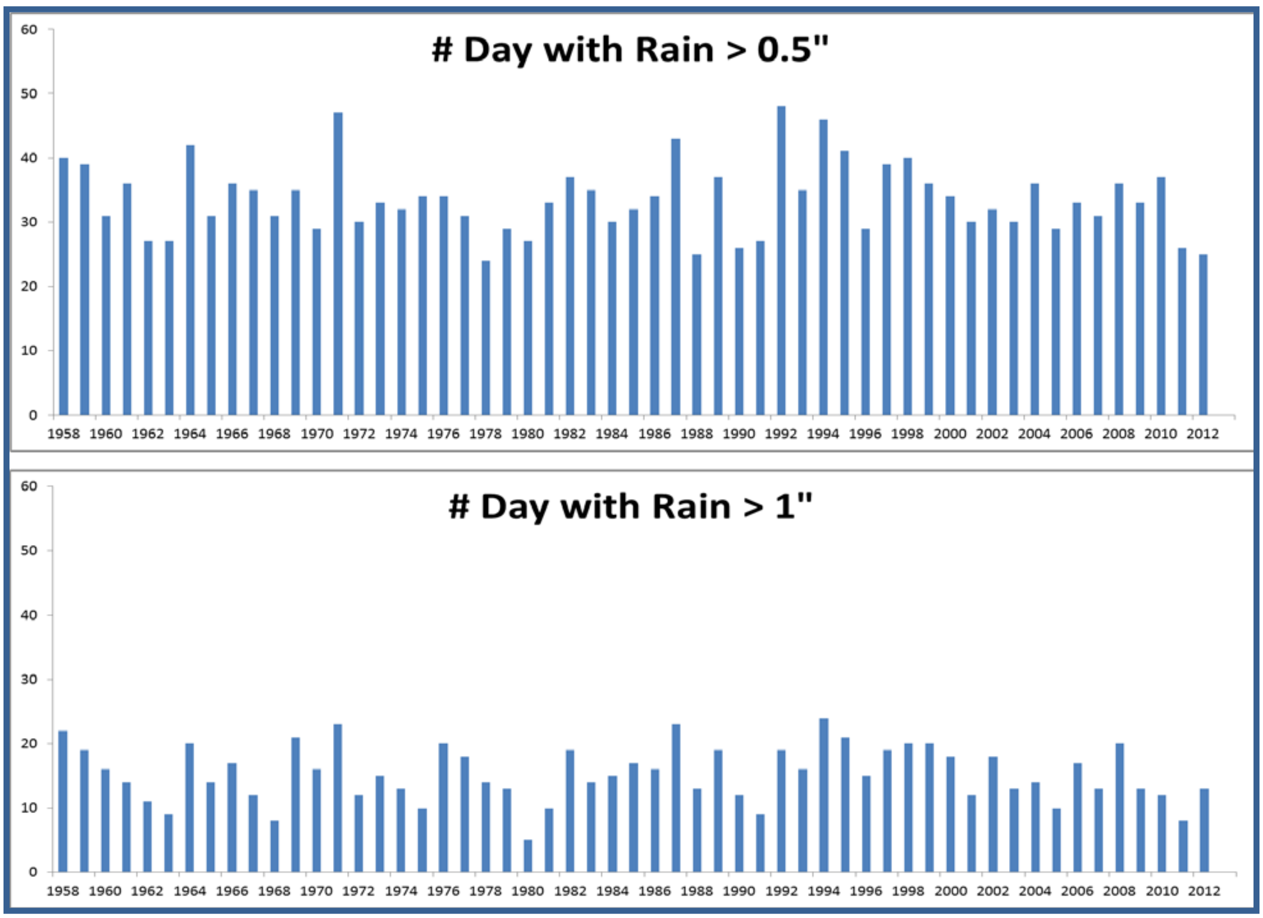


Figure D-5 *Occurrence of rain events at Brookgreen Gardens*

Summary Explanation of Fecal Coliform Data Trends

The following section provides explanations to the questions posed at the beginning of this element providing insight into the bacteria trends observed in Murrells Inlet dating back to 1992.

Which monitoring sites have had persistently elevated concentrations of fecal bacteria?

- Based on a review of the past 18 SC DHEC Management Area 04 Annual Shellfish Reports dating back to 1992, the monitoring sites which contravened the geometric mean standard most frequently were 04-01, 04-08, and 04-16. At each of these sites, the geometric mean standard was exceeded each year since 1992. Monitoring site 04-26 also exceeded the geometric mean standard on a frequent basis, representing 44% of the shellfish reports reviewed. Of note, all of these sites are in the shallower portions of Murrells Inlet where there is less tidal circulation.

- The review of the Management Area 04 shellfish reports also revealed that monitoring sites 04-01, 04-08, and 04-16 have exceeded the est. 90th percentile standard each year since 1992. Monitoring sites 04-02, 04-26, and 04-27 had a high frequency of exceeding the est. 90th percentile standard, having been above that threshold in 83% of the reports issued since 1992. Monitoring site 04-06 has exceeded the est. 90th percentile in 67% of the annual update reports. Meanwhile, 04-17a has been above the standard in 60% of the reports issued since 1992. These sites are also located in shallower areas of the inlet where there is less tidal circulation.

- Monitoring sites 04-01, 04-02, 04-08, and 04-16 have had the longest record of exceeding the est. 90th percentile and geometric mean shellfish harvesting fecal coliform standards. These sites are also currently experiencing some of the highest levels of fecal coliform as shown in **Appendix D**. All four of these sites were included in the original Murrells Inlet Fecal Coliform TMDL.

- Interestingly, the monitoring sites that form the boundaries of the Prohibited Zones surrounding the Murrells Inlet marinas (04-03A, 04-03B, 04-04B, and 04-04C) have relatively low levels of fecal coliform bacteria. The water depth near the marinas tends to be deeper allowing for more tidal circulation. SCDHEC regulations require shellfish beds within 1,000 feet of a marina to be classified as Prohibited for shellfish harvesting as a precautionary measure due to the potential for pollutants resulting from marina activities.

- The SC DHEC shellfish reports which exhibited the highest number of sites with water quality standard contraventions were from years 1992-1994, 2002-2004, and the last three reports, which incorporate monitoring data from 2008 through 2012.

Have the fecal coliform levels at each monitoring site increased or decreased over time?

To assess whether fecal coliform levels have increased or decreased over time, statistical trend tests were performed on the long-term SC DHEC monitoring data (1967-2011). Evidence for trends were explored using linear regression analysis of the data which were binned by decade and organized into boxplots. Evidence for trends were also explored using Mann-Kendall testing. Below is a summary of the observations and conclusions made based on the results of these statistical tests. The purpose of these tests was to give a weight of evidence indication of whether fecal coliform trends are increasing or decreasing at each site.

The Mann-Kendall test was also performed controlling for rainfall to examine the influence of wet weather on these time trends. It is important to note that an increasing bacteria trend does not necessarily mean that a station is located in a Restricted Shellfish Harvesting Area. Likewise, a decreasing bacteria trend does not necessarily mean that the monitoring station is located in an Approved Shellfish Harvesting Area.

- The statistical test results yielded evidence of increasing fecal coliform levels at 13 of the active monitoring sites within Murrells Inlet. The results indicated that there was a decrease in fecal coliform levels at seven active monitoring sites. In addition, there was a decreasing trend at five other deactivated monitoring sites, which are not currently being sampled.

- All of the marina sites had increasing trends.

- Some sites exhibited trends during wet and dry weather, some only during dry weather, and one only during wet weather.

Figure D-6 displays which monitoring sites have experienced increasing or decreasing fecal coliform statistical trends for the entire period of record analyzed. In addition, the figure indicates whether the trend is influenced by dry or wet weather conditions. **Appendix D** includes a chart with a summary of the statistical trends that are presented graphically in **Figure D-6**. The results show that monitoring sites with increasing trends are mostly clustered in the northern portion of the inlet. Meanwhile, sites indicating a decreasing fecal coliform trend are clustered mostly in the southern portion of Murrells Inlet.

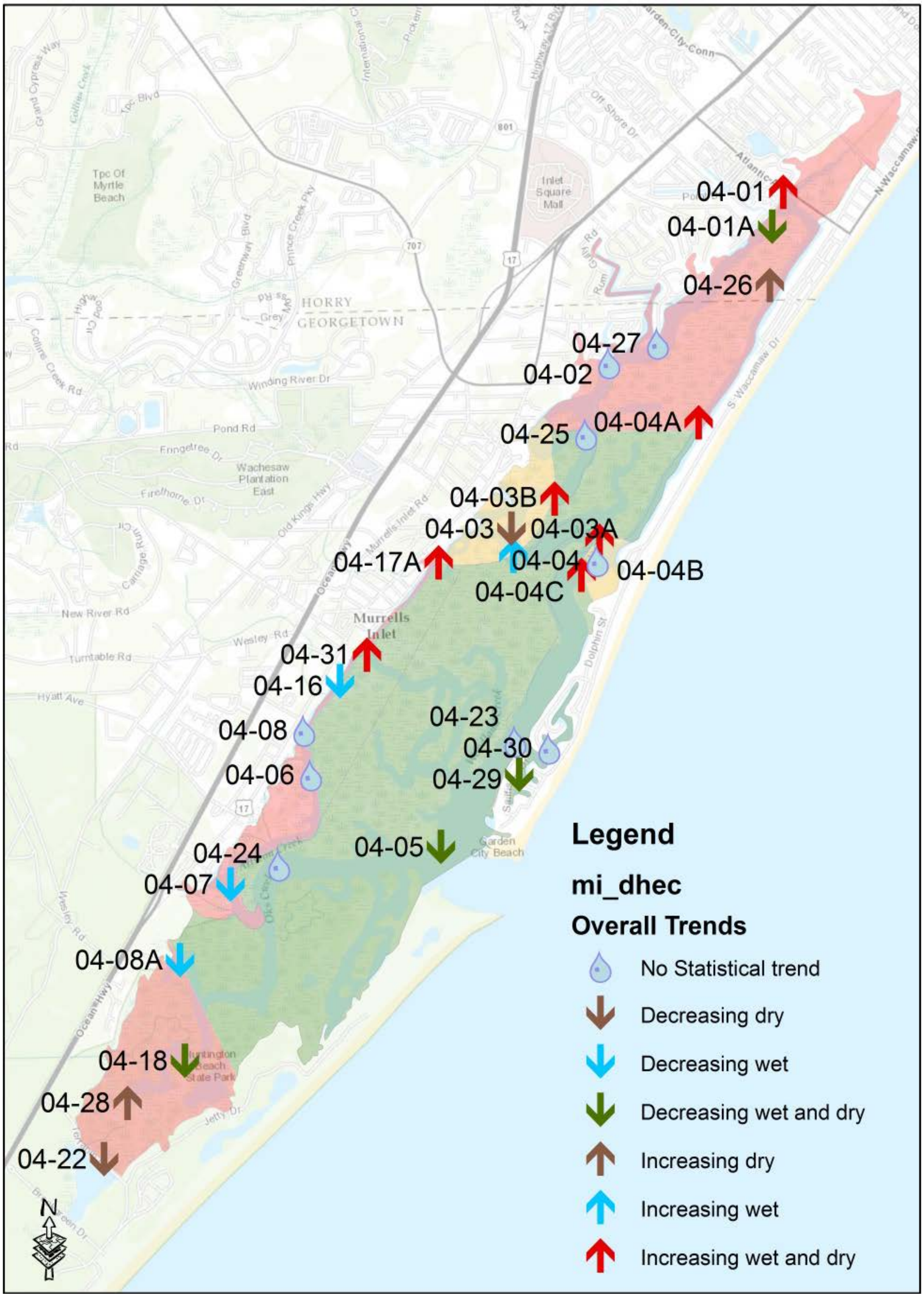


Figure D-6 *Long-term Fecal Coliform Trends in Wet and Dry Conditions*

Are fecal coliform concentrations higher under wet or dry weather conditions?

Precipitation data from the Brookgreen Gardens rain gauge were used to analyze the effect of rainfall on fecal coliform levels. The Brookgreen Gardens site is the longest running rain gauge operated by the National Climate Data Center within close proximity to Murrells Inlet. This rain gauge has also been used by state resource entities including SC DHEC in their shellfish monitoring program. The criteria used to characterize "dry weather" periods were fecal coliform samples collected within three days preceding total rainfall less than 0.5" inches. To characterize "wet weather" conditions, fecal coliform samples collected within three days following rainfall totals greater than 0.5" inches of rain was the criteria used. Statistical tests are imperative for this type of analysis to resolve trends from fecal coliform datasets that have high temporal variability. In other words, it is not uncommon for a dry weather fecal coliform reading to be higher than is typical for a wet weather fecal coliform value. A non-parametric Mann Whitney U test for differences in the wet versus dry samples from each site was performed using data from the 2000-2009 decade. In addition to rainfall, other environmental conditions such as salinity and tidal levels can also influence fecal coliform levels.

- Of the sites monitored from 2000-2009, 16 of the 28 sites had statistically significant evidence of fecal coliform concentrations being higher during wet weather as compared to dry weather. The sites with significantly higher fecal coliform levels during wet weather conditions are: 04-01, 04-01A, 04-02, 04-03B, 04-04, 04-04C, 04-06, 04-08A, 04-17A, 04-18, 04-25, 04-26, 04-27, 04-29,04-30, and 04-31. Note that fecal coliform levels at some of these sites are consistently meeting shellfish water quality standards.

What factors could be influencing the time trends in fecal coliform concentrations?

Perhaps the most critical aspect of the baseline assessment is being able to properly interpret the findings to understand the natural and anthropogenic factors that are influencing the fecal coliform trends in Murrells Inlet. Below are a few conclusions about the principal factors that influence fecal coliform levels in the Murrells Inlet watershed:

- Drought characterized by both the total annual rain accumulation and the number of rain events may have an impact on the occurrence of high fecal coliform levels. The Southeast region of the United States has experienced moderate drought conditions over the course of the past decade. It is suspected that a lower frequency of rain can lead to higher fecal coliform concentrations by increasing the concentration in the first flush of stormwater runoff during rainfall events. If runoff is the primary mechanism by which fecal bacteria are conveyed into the inlet, then higher concentrations in runoff will lead to higher concentrations in the receiving waters.

- The Murrells Inlet landscape has changed significantly over the past few decades, due to population growth and development. It is suspected that as impervious surfaces such as roadways and buildings become more prominent features in the landscape, fecal coliform levels would likely increase due to diminished retention leading to enhanced runoff. As **Table C-2** and **Exhibit C-1** illustrate, using curve numbers as an indicator of the drainage characteristics of each subwatershed, there has been a significant increase in the amount of impervious surface area in Murrells Inlet over the past ~18 years. An increase in stormwater runoff rate and volume would be expected to increase the transport of fecal bacteria from the adjacent landscape into the estuary.

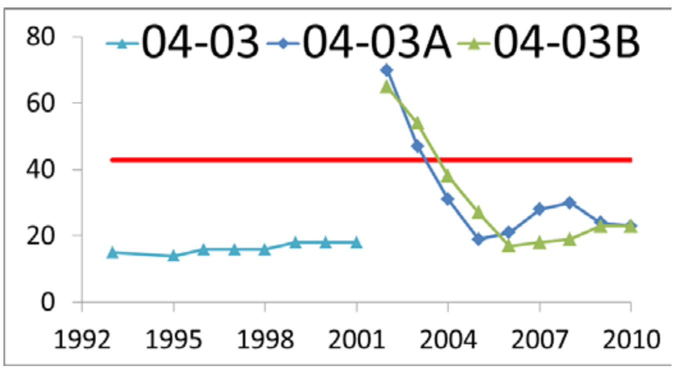
- A related factor is the stormwater infrastructure in Murrells Inlet. Increased stormwater piping and ditching has progressively altered the natural hydrology over time likely resulting in enhanced transport of fecal bacteria off the land and ultimately into Murrells Inlet. Stormwater retention facilities installed during this period of growth partially mitigates this impact to some degree.

- A consensus observation that has been made by local residents and stakeholders is the noticeable siltation that has occurred in the main channels and tidal creeks in many portions of the watershed. Parsonage Creek in particular is an area where this trend has become very pronounced, even to the point where navigation at low tide has become difficult. It has been observed that salinity plays an integral role in moderating bacteria levels in freshwater inputs, hence the importance of tidal flushing in coastal estuary systems. With shallower tidal creek channels, bacteria concentrations may have become more influenced by freshwater tributaries and ditches draining to the estuary. Resuspension of fecal coliform can also occur when sediments are disturbed especially in areas of shallow water depth.

Figure D-7 *Upper reaches of a tidal creek showing signs of sedimentation. (Photo courtesy of Dr. Dan Hitchcock, Clemson University).*

- Studies have also shown that bacteria tend to bind to sediment particles where they can survive and even propagate for long periods of time. In an aquatic environment, sediment can shield bacteria from sunlight, which reduces the rate of UV light based disinfection. The increased sediment load whether originating upstream or disturbed in the shallow creeks provides an environment more suitable for bacteria survival. These bacteria most likely have an influence on the increased fecal coliform levels measured over time, particularly at monitoring sites closest to the immediate shoreline of Murrells Inlet.

- A very striking example of how sediment loads can influence bacteria levels can be seen in the monitoring trends at Site 04-03, which is located near Captain Dick's Marina. In 2002, the marina was dredged to increase depth and improve navigability. Immediately after dredging, the monitoring data showed that the fecal coliform levels increased substantially, indicating that perhaps it occurred in response to the dredging process through resuspension of the bacteria present in the sediment. Over the next several years, the fecal coliform levels decreased significantly, likely due to the removal of the sediment which had become an ideal habitat for bacteria survival.



(Note that the data being plotted here are based on 3-year running est. 90th percentiles, so high values observed immediately after the dredging are propagated through the next three reporting increments, in this case 2002-2004, 2003-2005 and 2004 to 2006. The red line in the graph represents the WQS for the 90th percentile. The y axis is the fecal coliform concentration in MPN/100 mL)

The conclusions outlined above were integral focal points in evaluating watershed management opportunities and corresponding recommendations outlined in **Element H: Watershed Management Measures**.

MURRELLS INLET VOLUNTEER MONITORING PROGRAM

In partnership with Coastal Carolina University's Waccamaw Watershed Academy and both Horry and Georgetown counties, Murrells Inlet 2020 sponsors a volunteer water monitoring program in Murrells Inlet. Spanning both counties, volunteers have collected samples at eight sites twice monthly since 2008. **Figure D-8** displays the locations of each of the monitoring stations. For each sample collected, the following water quality parameters are measured: dissolved oxygen, pH, temperature, salinity, conductivity, turbidity, total dissolved solids, nitrate/nitrite/ammonia, total coliform bacteria, and *E. coli*. The Murrells Inlet Water Monitoring Program is a non-regulatory programs which serves multiple purposes including engaging local residents in an educational stewardship activity. It also enables local governments to track water quality improvements following the implementation of a project and to be aware of and promptly respond to accidental emergencies or cases of illicit discharge.

1. Woodland Pond
2. Point Drive Canal
3. Rum Gully Creek
4. Marina Colony Pond
5. Harrelson's creek
6. Boat House Run creek
7. Bike Bridge creek
8. Oyster Landing Beach

Figure D-8 *Location map of the eight sampling sites of the Murrells Inlet Volunteer Monitoring Program. Site names are in order from North to South. (Courtesy of Coastal Carolina University)*

As monitoring data continues to be collected and water quality trends can be more fully analyzed, the utility of the volunteer program will become even more significant. The power of monitoring data grows as a long-term database is generated. In fact, the data set is long enough now to analyze for data trends of the five year period for which data have been collected. Finally, the volunteer monitoring program has and continues to build an informed, knowledgeable citizen base that have become advocates for water quality protection within the watershed, which is critical to supporting and funding planning and implementation activities.

The volunteer monitoring program collects data on two indicator bacteria species, *E. coli* and Total Coliform, which can provide insight into water quality conditions that may affect Shellfish Harvesting Waters within Murrells Inlet. While the FDA requires SC DHEC to monitor fecal coliform in designated Shellfish Harvesting Waters, EPA now requires *E. coli* monitoring in classified freshwaters and Enterococcus in classified saltwaters for recreational uses as they are regarded as better indicators of human health risk from water contact.

Figure D-9 *Woodland Drive Pond Volunteer Monitoring Site (Photo courtesy of Daniel Newquist, Waccamaw Regional COG)*

The eight monitoring sites were chosen to obtain a geographically representative sampling dataset from the northern to southern end of the watershed and to also investigate water quality conditions in the main tributary creeks which are the primary transport mechanisms for stormwater runoff flows from the surrounding drainage basins.

Table D-3 provides summary E. Coli data results for each monitoring site.

Table D-3 Murrells Inlet Volunteer Monitoring Program E. Coli (CFU/100ml) Statistics

Site Name	*Closest SC DHEC Site*	*# Samples*	*Median*	*Max*
Woodland Drive Pond	*04-01*	*122*	*600.0*	*8,500.0*
Point Drive Canal	*04-01*	*121*	*67.0*	*3,667.0*
Rum Gully Creek	*04-27*	*120*	*0.0*	*433.0*
Marina Colony Pond	*04-25*	*119*	*67.0*	*4,500.0*
HS	*04-17A*	*122*	*800.0*	*9,400.0*
BHR	*04-16*	*122*	*1,650.0*	*14,400.0*
Bike Bridge	*04-07*	*121*	*200.0*	*5,250.0*
Oyster Landing Beach	*04-08A*	*120*	*0.0*	*533.0*

Source: The Murrells Inlet Volunteer Monitoring Program. Data from May 20, 2008 to October 8, 2013

Table D-4 provides summary Total Coliform data results for each monitoring site.

Table D-4 Murrells Inlet Volunteer Monitoring Program Total Coliform (CFU/100ml) Statistics				
Site Name	***Closest SC DHEC Site***	***# Samples***	***Median***	***Max***
Woodland Drive Pond	*04-01*	*122*	*2,234.0*	*33,300.0*
Point Drive Canal	*04-01*	*121*	*533.0*	*14,400.0*
Rum Gully Creek	*04-27*	*120*	*33.0*	*7,967.0*
Marina Colony Pond	*04-25*	*119*	*500.0*	*10,400.0*
HS	*04-17A*	*122*	*4,200.0*	*33,467.0*
BHR	*04-16*	*122*	*5,200.0*	*33,000.0*
Bike Bridge	*04-07*	*121*	*1,400.0*	*34,267.0*
Oyster Landing Beach	*04-08A*	*120*	*33.0*	*5,300.0*
Source: The Murrells Inlet Volunteer Monitoring Program. Data from May 20, 2008 to October 8, 2013				

Below are some general observations on the trend analysis conducted on the available Murrells Inlet Volunteer Monitoring Program data:

- Data collected by the Murrells Inlet Volunteer Monitoring Program from July 2009 to May 2012 has shown persistent elevated levels of E. coli at the BHR, HS, Woodland Drive Pond and Bike Bridge monitoring sites.
- The Murrells Inlet Volunteer Monitoring Program has detected a declining trend in *E. coli* /Total Coliform levels for the BHR and HS monitoring sites since the monitoring program was launched in May 2008.
- In assessing the volunteer monitoring sites, four of the sites showed statistical evidence for higher *E. coli*/ Total Coliform levels during wet weather periods. These sites were Rum Gully Creek, Oyster Landing, Bike Bridge, and Marina Colony Pond.

GEORGETOWN COUNTY UPSTREAM MONITORING

The Georgetown County Stormwater Division provided funding to expand the volunteer monitoring program to include a more detailed investigation in four subwatersheds to help target future stormwater management efforts. The goal was to better understand significant variability in the bacteria levels at the volunteer monitoring sites and to help identify or rule out certain sources of bacteria. The BHR, HS, and Bike Bridge subwatersheds plus Huntington Beach State Park (added to better understand wildlife contribution) were sampled. The sampling locations were selected based on the subwatershed delineations and time of concentration flow path information outlined in the maps included in **Appendix A**. This seven month monitoring initiative was intended to help make investigatory observations, however given the limited samples collected it was not intended to provide statistically significant conclusions of the data generated.

In summary, below is a list of observational findings from this additional upstream monitoring:

- No evidence of septic tank failures or sewer line leakages were observed in any of the four subwatersheds.
- Bacteria levels have been highly variable from one sample date to the next.
- Average bacteria levels tend to be higher in close proximity to the inlet.
- Bacteria levels in undeveloped watersheds were very similar to those in residential areas.
- Prolonged rainfall seems to reduce bacteria levels as the first flush from a storm had already flushed accumulated animal waste.
- Raccoon and opossum tracks are regularly observed near drainage ditches and small streams. These tracks occurred at the same times that bacteria measurements were high, leading to the conclusion that much of the bacteria contributions, especially during periods of low flow, is the direct result of wildlife. Based on this and other observations, the steering committee infers that wildlife populations represent a significant pollutant load for fecal bacteria in the subwatersheds studied.
- It is estimated that open stormwater ponds remove on average 67% of E. coli and 86% of the total coliform bacteria entering the ponds. This is consistent with published removal efficiencies
- It is estimated that vegetated ponds provide up to 95% removal of E.coli and 75% of total coliform bacteria. This is consistent with published removal efficiencies.

Figures D-10 and D-11 *There are extensive portions of the southern end of the watershed that are heavily wooded making it ideal habitat for many wildlife species. Volunteers frequently observed raccoon tracks along creeks and nearby drainage ways. (Photos courtesy of Dr. Dan Hitchcock, Clemson University, and Gary Weinreich, Murrells Inlet Volunteer Monitoring Program)*

By using this subwatershed monitoring approach, watershed managers can assess bacteria levels upstream and downstream of various landscape features such as stormwater retention ponds as an example. This type of monitoring strategy can be very enlightening and inform decisions regarding effective stormwater management practices. Recommendations for continued utilization are outlined in **Element K: Water Quality Monitoring Strategic Plan**.

HORRY COUNTY MICROBIAL SOURCE TRACKING INITIATIVE

As monitoring technologies continue to advance, watershed managers are relying on new methods to conduct their monitoring efforts. An emerging class of monitoring techniques, known as source tracking, aims to detect chemical or microbial indicators that can more precisely identify the pollutant source of origin affecting nearby water quality conditions. Samples that are collected can be examined to determine if the genetic markers present can be traced to a particular animal species or group such as a human, dog, bird, cat, etc. Based on this information, watershed managers can better understand the sources of the bacteria, including wildlife, and determine whether reduction efforts are appropriate.

Coastal Carolina University has developed capacity through their Environmental Quality Laboratory to provide local communities with this monitoring technology. To date, source tracking has been effectively utilized to assess potential sources of pollution in the Town of Briarcliffe Acres and in the Withers Swash watershed area of Myrtle Beach. Horry County has begun to apply this monitoring approach in the Murrells Inlet watershed as well. Beginning in 2012, the Horry County Stormwater Department established nine source tracking monitoring sites at strategic locations in the upstream reaches of the watershed and in the Main Channel near Rum Gully Creek.

The initial samples have produced some important results:

- Canine signals have been high at multiple sites, with the highest concentrations occurring after a rainfall event. This provides support of a suspected source of bacteria and should lead to targeted public outreach and enforcement regarding pet waste disposal.
- Human signals have been detected in three samples to date. One of the samples was taken near the Woodland Drive Pond Volunteer Monitoring Site. This sample also detected caffeine and optical brightener levels which are human indicator chemical tracers. The other sample was taken at SC DHEC site 04-01. Optical brightener indicators were also detected at this site. An additional sample near the Point Drive Canal Volunteer Monitoring Site also showed signals for optical brighteners and caffeine, both are indicators of human sources. These are very important initial findings regarding human contributions of pathogenic bacteria, which is necessary when investigating the extent of the problem and the remedies needed to mitigate the concern.
- Bird signals were widespread across the sampling sites.

Figure D-12 below displays the locations of each of the sampling sites.

Figure D-12 *Horry County microbial source tracking monitoring site locations.*

The microbial source tracking monitoring approach is likely to continue to be a useful tool in assessing water quality conditions in Murrells Inlet in the future. Georgetown County Stormwater Department is preparing to launch a similar monitoring initiative in the upcoming year.

The analysis and findings of the monitoring initiatives outlined in this element resulted in a prioritization of subwatersheds for future watershed management recommendations. An overview of the priority subwatersheds is included in **Element F** followed by a detailed overview of recommended near-term and long-term best management practices in each of the identified subwatersheds and across the entire watershed in **Element H**.

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