Journal of South Carolina Water Resources, Volume 8, Issue 1, Pages 33–47, 2021

NPDES Phase II Stormwater Rule—Integrating Community Engagement and Engineering Education

Monica Gray[1]

AUTHOR: [1]Associate Professor & Engineering Director, Coastal Carolina University, P.O. Box 261954, Conway, SC 29528-6054, USA.

Abstract. The Engineering Program at Coastal Carolina University seeks to train future leaders who will develop and implement sustainable solutions to global challenges by engaging students in real-world, community-based projects starting with the two-course Cornerstone Sequence. The program's vision is to: (1) increase participation of underrepresented and minority groups and address the persistent degree attainment gap in engineering; (2) create a learning and professional environment where diversity is celebrated as seminal to program success and where all students, particularly underrepresented and minority groups, thrive and excel; and (3) develop future leaders who are knowledgeable and who are able to apply scientific and engineering principles to impact the well-being of the global society and its environment. The Coastal Waccamaw Stormwater Education Consortium (CWSEC) members include six citizen science education agencies and eight municipal separate storm sewer systems (MS4s) serving Horry and Georgetown Counties in South Carolina. The mandate of the consortium is to help local governments meet EPA's National Pollutant Discharge Elimination System (NPDES) Stormwater Management Program Phase II Rule by implementing the following Minimum Control Measures (MCM): (1) Public Education and Outreach on Stormwater Impacts, and (2) Public Participation/Involvement. The consortium and the Engineering Program have partnered on MCM (1) and (2) by: (i) Integrating consortium activities in the ENGR 199/299 Cohort Grant Challenge Cornerstone Course Sequence's deliverables. The objective of this two-course sequence is for students to identify and formulate complex engineering problems utilizing the National Academy of Engineering's (NAE)14 Grand Challenges for Engineering in the twenty-first century as a framework for community-based projects; and (ii) Collaborating with representatives from municipalities and educational providers that are members of the consortium to provide current stormwater-related engineering design challenges to student groups. This paper reports on an initial, successful prototype of this partnership that occurred during the 2020 fall semester. Projects were focused on various aspects of the NAE Grand Challenge—"Provide Access to Clean Water." The long-term vision is to integrate consortium activities into the engineering curriculum while leveraging the talent of engineering students to solve stormwater challenges in the community.

INTRODUCTION

One of the main objectives of the Clean Water Act (CWA) is to promote public health by reducing pollution in the nation's water bodies. Stormwater runoff is a major cause of nonpoint source pollution resulting in water quality deterioration in the urban water cycle (Ma et al. 2018). Stormwater runoff is most sensitive to significant variations in impervious surfaces, which results from rapid urbanization and subsequent land-use changes (Gold et al. 2017; Shukla et al. 2018; Yang and Toor 2018). Over the last decade, coastal counties experienced increases in population density over three times the national average (Freeman et al. 2019). Further, these communities are more susceptible to storms and concomitant surface water pollution due to runoff; their close proximity to the sea means higher rainfall intensity for the same design storm and they are generally flat, which increases the time of concentration (i.e., water stays in communities longer).

More frequent extreme weather and obsolete or non-existent stormwater management regulations, combined with rapid development, have increased stormwater runoffs, resulting in expensive and sometimes catastrophic flooding, as well as water quality issues. These challenges are especially relevant to South Carolina's Coastal Plain (Blair et al. 2016). In the last few years, the area has been affected by at least one major hurricane with subsequent flooding. The pace of development is accelerating, and the resulting floods affect low socioeconomic status areas at higher rates and greater intensity (Dickes et al. 2016; Ellis et al. 2017; Kuhl 2019; Mal-

lin et al. 2019; Schroer et al. 2018). Horry and Georgetown Counties are two of eight coastal counties in South Carolina. Horry County is the second-fastest-growing Metropolitan Statistical Area in the country; its population and its housing development have doubled in the last three decades and are on pace to double in the next 20 years. Georgetown County's population grew over 601% within a 40-year period. Both counties constitute the Grand Strand, which sees up to 18 million tourists annually (Horry County Government 2019). The continual growth as a tourist attraction naturally leads to land development to support the economy and concomitant increases in impervious surfaces.

Urban development and resulting stormwater discharges are regulated under the CWA's National Pollutant Discharge Elimination System (NPDES) permit program. The program made it illegal to discharge any pollutant as a point source into waters of the United States without an NPDES permit (US EPA 2005). While unique origins of stormwater and subsequent *in situ* pollutants are technically nonpoint sources, runoff flows are defined by the South Carolina Department of Health and Environmental Control (SCDHEC) as point sources under the South Carolina Pollution Control Act and therefore requires an NPDES permit (Pollution Control Act of 1962). The CWA initially focused on industrial and municipal sewerage systems, but it was expanded to also include pollutants reduction in stormwater systems (Pines 2005). Phase II of the two-phase Stormwater Rule was published in December 1999 and focused on small Municipal Separate Storm Sewer Systems (SMS4s). The Phase II program includes six Minimum Control Measures (MCMs):

- Public Education and Outreach on Stormwater Impacts
- Public Involvement and Participation
- Illicit Discharge Detection and Elimination
- Construction Site Stormwater Runoff Control
- Post-Construction Stormwater Management in New Development and Redevelopment
- Pollution Prevention and Good Housekeeping for Municipal Operations

The Coastal Waccamaw Stormwater Education Consortium (CWSEC) is one of three regional consortia serving South Carolina's eight coastal counties. CWSEC members include six citizen science education agencies and eight municipal separate storm sewer systems (MS4s) serving Horry and Georgetown Counties (see Table 1). CWSEC was formed in 2004 to facilitate regional collaboration of stormwater educational efforts in response to current and future requirements. The mandate of the consortium is to help local governments meet EPA's National Pollution Discharge Elimination System (NPDES) Stormwater Management Program Phase II Rule by implementing the first two of the six Minimum Control Measures (MCM):

- Public Education and Outreach on Stormwater Impacts
- Public Participation and Involvement

About 50% of the engineering majors at Coastal Carolina University identify as underrepresented minorities. In today's increasingly global economy, there is an urgent need for a diverse engineering workforce (Gray and Lundy 2016). However, according to the American Society for Engineering Education's "Going the Distance" report, 53.6% of Hispanic, 61.4% of Native American, 61.7% of African American, and of 49% female students who enter engineering programs do not graduate in this major (ASEE 2012). This translates to an engineering workforce comprised of about 6% Hispanics, 0.3% Native American, 4% African Americans, and 13% females, according to the latest National Science Foundation's report (NSF 2019). With such high attrition rates among minorities and underrepresented groups, changing the current engineering workforce's diversity portfolio is of grave

Table 1. Coastal Waccamaw Stormwater Education Consortium Members

Citizen Science Educational Providers	Municipal Separate Storm Sewer Systems (MS4s)
1. Coastal Carolina University's Waccamaw Watershed Academy	1. Horry County
2. Clemson's Carolina Clear	2. City of Conway
3. Murrells Inlet 2020	3. Georgetown County
4. North Inlet-Winyah Bay National Estuarine Research Reserve (NERR) Coastal Training Program & Public Education Program	4. Town of Surfside Beach
5. South Carolina Sea Grant Consortium	5. City of North Myrtle Beach
6. Winyah Rivers Foundation Waccamaw Riverkeeper Program	6. City of Conway
	7. Town of Atlantic Beach
	8. Town of Briarcliffe Acres

national importance and requires a plethora of high-impact approaches. Successful high-impact practices include introducing design and research early and partnerships with local communities to positively affect interest and persistence in engineering programs, thereby strengthening the educational pipeline (Chang 2002).

The Engineering Program at Coastal Carolina University seeks to train future leaders who will develop and implement sustainable solutions to global challenges by engaging students in real-world, community-based projects starting with the two-course Cornerstone Sequence. The program's vision is to: (1) increase participation of underrepresented and minority groups and address the persistent degree attainment gap in engineering; (2) create a learning and professional environment where diversity is celebrated as seminal to program success and where all students, particularly underrepresented and minority groups, thrive and excel; and (3) develop future leaders who are knowledgeable and who are able to apply scientific and engineering principles to impact the well-being of the global society and its environment. As a graduation requirement, each student must complete at least one experiential opportunity that fulfills the following ABET accreditation student outcomes: (1) an ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics; and (2) an ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.

This paper reports on a case study of an initial partnership prototype between the CWSEC and the Engineering Program that occurred during the 2020 fall semester. The partnership synergistically leveraged the consortium's mandate to help local governments meet MCMs (1) and (2) to educate and involve the public with the Engineering Program's goals to introduce design and research early in the curriculum as a retention practice. Projects were focused on various aspects of the National Academy of Engineering (NAE) Grand Challenge for Engineering in the Twenty-First Century—"Provide Access to Clean Water." This challenge focuses on new threats, such as stormwater, to the world's water supplies and the need for global solutions (NAE 2021). The long-term vision is to integrate consortium activities into the engineering curriculum while leveraging the talent of engineering students to solve stormwater challenges in the community. The target audiences for this work includes MS4s and stormwater consortia who are exploring ways to satisfy NDPES MCMs (1) and (2) and engineering faculty and students seeking ways to connect the academic classroom experience with real-world challenges and opportunities, particularly in the area of stormwater management and control.

BACKGROUND AND RELATED WORK

In its 2000 Fact Sheet series on Stormwater Phase II Final Rule (EPA, 2005), the EPA discussed why it was necessary to have MCMs (1) and (2). That information is summarized as follows:

1. Public Education and Outreach on Stormwater Impacts—an educated community is integral to successful stormwater management because it fosters greater support and compliance as a result of increased understanding and subsequent ownership among citizens.
2. Public Participation and Involvement—encourages valuable inputs and an active role in the development and implementation of watershed-based stormwater management plans. This allows for broader public support, shorter implementation schedules, a treasure trove of intellectual resources, and the potential for braiding of resources from other community and government programs.

Over the last sixteen years, the consortium has fulfilled its mandate via a number of activities, such as:

- Public Education and Outreach on Stormwater Impacts
- Classroom education on stormwater
- Education displays, pamphlets, and other stormwater educational materials
- Low-impact development training
- Pet waste management
- Using the media
- Public Participation and Involvement
- Reforestation programs
- Stakeholder meetings
- Storm drain stenciling
- Stream cleanup and monitoring
- Volunteer monitoring

The consortium has previously engaged undergraduate students through its Campus Volunteer Water Quality Monitoring program. The goal of the program is to provide an assessment of water quality conditions in the stormwater ditches and retention ponds on campus, all of which eventually send waters off campus toward the Waccamaw River, a slow-moving, blackwater river and one of the primary sources of drinking water in Horry County. Sampling is conducted weekly during the academic semesters. The data are being used to evaluate whether water quality is improving or degrading over time at some or all the sites using a watershed

approach. This project is a natural progression of the past iteration of the Campus Monitoring Program whereby the activities are integrated into the courses and curriculum of the newly developing engineering program, simultaneously fulfilling curricular and compliance requirements while expanding to include community members.

PROJECT OBJECTIVES/GOAL

The goals of the project are:

- Initiate collaboration between the CWSEC and the Engineering Program to:
- Increase participation of underrepresented and minority groups and address the persistent degree attainment gap in engineering;
- Create a learning and professional environment where diversity is celebrated as seminal to program success and where all students, particularly underrepresented and minority groups, thrive and excel; and
- Develop future leaders who are knowledgeable and are able to apply scientific and engineering principles to impact the well-being of the global society and its environment.
- To train future engineering leaders by engaging students in real-world community-based projects and assessing the following ABET student outcomes:
- An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics; and
- An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Help local governments meet EPA's National Pollution Discharge Elimination System (NPDES) Stormwater Management Program Phase II Rule by implementing the first two of the six Minimum Control Measures (MCM); namely:
- Public Education and Outreach on Stormwater Impacts
- Public Participation and Involvement.

MATERIALS AND METHOD

Nine (9) groups of 2 to 3 engineering students/designers were assigned community-based stormwater-related projects as well as community client(s). Their goals were to work with clients to determine the need/problem, formulate problem and design statements, and propose solutions. As a result of the ongoing COVID-19 pandemic, all interactions were done virtually via emails and videoconferencing. At the end of the semester, students, clients, faculty, and other community members participated in a virtual cornerstone colloquium, where student groups presented their work. The consortium and Engineering Program, therefore, partnered on MCMs (1) and (2) by:

- Integrating consortium activities in the ENGR 199/299 Cohort Grant Challenge Cornerstone Course Sequence's deliverables. The objective of this two-course sequence is for students to identify and formulate complex engineering problems utilizing the National Academy of Engineering's 14 Grand Challenges for Engineering in the 21st century as a framework for community-based projects. Projects, including a collaboration with Georgetown County Stormwater, focused on various aspects of the Grand Challenge—"Provide Access to Clean Water."
- Collaborating with representatives from municipalities and educational providers who are members of the consortium to provide current stormwater-related engineering design challenges to student groups.

RESULTS

The course description was as follows: Great engineering achievements such as safe drinking water and electricity have revolutionized society. While these achievements are remarkable, future engineers are faced with many more great challenges and opportunities yet to be realized. With input from people around the world, an international group of leading technological thinkers were asked to identify the Grand Challenges for Engineering in the twenty-first century. Their 14 game-changing goals for improving life on the planet, are introduced in this course as a means introducing complex engineering problems, how to identify and formulate them by applying principles of engineering, science, and mathematics.

The resulting projects are summarized in Tables 2 through 10.

Table 2. Project #1: Water Treatment in the Time of Hurricanes—Bull Creek Regional Water Treatment Plant

Project Title	**Project #1: Water Treatment in the Time of Hurricanes—Bull Creek Regional Water Treatment Plant**
Community Client/ Technical Advisor (s)	Grand Strand Water and Sewer Authority
Target Consumers/ Stakeholders	Water Treatment Operators, SCDHEC and Water Customers in the Community
Project Scenario & Context	The Bull Creek Regional Water Treatment Plant can treat as much as 45 million gallons of water each day. Untreated surface water is pulled from Bull Creek, which is an arm of the Great and Little Pee Dee Rivers. The turbidity, color, organics, and other water quality pollutants are different in each tributary and must be considered in the water treatment process. The water quality in the Little Pee Dee is characterized by high tannins, fulvic and humic acids (high color and organics), and low turbidity. While the water from the Great Pee Dee River has less color and organic content (i.e., easier to treat), it has more solids that result in higher turbidity. During normal flows, the proportion of water volumes from the Great Pee Dee tributary and Little Pee Dee tributary into Bull Creek is approximately 4:1, respectively. During heavy rainfall events, the volumetric flow proportion changes sometimes flip from 4:1 to 1:4 because the Little Pee Dee is closest to the coast and receives more rainfall during localized rain events. This wild swing in volumetric flow results in a drastic change in the quality of the raw water and thus the dosing of treatment chemicals. During normal flows, the Environmental Quality Lab on site at the Bull Creek plant runs Total Organic Carbon (TOC) analysis to determine the dosing requirements each day. In response to heavy rainfall events when the water quality is rapidly changing, sometimes hourly, Water Treatment Operators must figure out a way to quickly determine the concentrations of pollutants in the treatment plant's influent in order to effectively treat the raw water and produce high-quality, safe drinking water for the community.
Problem Statement	The quality of raw water entering Water Treatment Plants (WTP) changes continually and more drastically during storm events. TOC is the total amount of organic carbon in natural waters and can combine with disinfectants to create carcinogenic a Disinfectant By-Product. TOC removal is therefore regulated by law, and the water treatment process must be optimized to ensure high-quality and safe, potable water to customers. While the Jar Test Method is the gold standard for determining the concentration of TOC present and the optimal coagulant and dosage for a WTP's raw water, it takes a long time and requires qualified laboratory technician skills that are not always available, especially during storm events.
Design Statement	The Team is tasked with exploring rapid and easy-to-use substitute(s) or surrogate(s) to the Jar Test Method for TOC analysis. The new Method (s) should be fast, easy for WTP Operators to learn and carry out, and must be as effective and accurate as the Jar Test Method. Ideally, it will employ current water quality analysis methods already carried out by WTP Operators.

Table 3. Project #2: Treating Conway's Wastewater—Managing Filamentous Microbial Growth in Sewer Lines

Project Title	**Project #2: Treating Conway's Wastewater—Managing Filamentous Microbial Growth in Sewer Lines**
Community Client/ Technical Advisor (s)	Grand Strand Water and Sewer Authority
Target Consumers/ Stakeholders	Wastewater Treatment Operators, Community Residents, SC DHEC, Riverkeeper
Project Scenario & Context	The Conway Wastewater Treatment Plant (WWTP) serves the city of Conway and a large portion of the western areas of Horry County, and it is rated to treat up to 4.0 million gallons of wastewater per day. The treated effluent is discharged into a swampland on the Waccamaw River, which is a drinking water source for the county and historically suffers from low dissolved oxygen levels. The wastewater treatment process starts as soon as it leaves homes and businesses. This is because the microorganisms that naturally occur in wastewater play an important role in the wastewater treatment process. Therefore, the time spent in the water, the flow rates and volumes moving through the collection system, and the pollutants in the wastewater stream impact the treatment process at the plant. For example, warmer or colder weather or the presence of grease can significantly change the microbial species, concentrations, and activities, which in turn, affects the treatment process. Cities like Conway and Wastewater Treatment Operators need ways to quickly determine and anticipate changes in pollutants and microbial makeup of the influent flowing into WWTPs if they are to effectively treat it before discharging to the environment.
Problem Statement	As sewage is transported in the hundreds of miles of the urban sewer pipe infrastructure, microorganisms proliferate and become a part of the influent flow to Conway WWTP. These microorganisms in general are beneficial and are employed in the treatment process; however, some, particularly filamentous microbes, can adversely impact the removal of pollutants from the wastewater. WWTPs require low levels of filamentous microorganisms because an overabundance causes sludge bulking, pin-floc/poor flocculation, foaming (biological), rising solids (denitrification), and ultimately poor settling of solids. This in turn results in increased treatment cost and poor effluent quality to receiving water bodies, such as the Waccamaw River, which is a drinking water source for the county and which historically suffers from low dissolved oxygen levels.
Design Statement	The Team has been tasked with researching and proposing ways to effectively predict and manage growth of filamentous microbes in sewer lines in transit to the Conway WWTP. This solution needs to reduce the proliferation of filamentous microorganisms while simultaneously increasing aerobic bacteria concentrations. If possible, the solution should not only solve the problem of the overabundance of filamentous bacteria in the collection system but also determine the cause of the overabundance to ensure future predictions. The solution should not simply be a maintenance correction, but rather a permanent answer to the problem. The proposal needs to be completed by December 4 and it must be cost-efficient. The solution should ensure compliance with SCDHEC standards per the WWTP's operation permit for effluent discharged to the Waccamaw. The Team must also prepare an innovative and creative educational and outreach program for management of Fats, Oils and Grease (FOGs) specific to the communities in the treatment area of the plant.

Table 4. Project #3: Covington Lake—Pond Volume Assessment and Simulation

Project Title	**Project #3: Covington Lake—Pond Volume Assessment and Simulation**
Community Client/ Technical Advisor (s)	Covington Lake Homeowners Association (HOA), Residents and Board
Target Consumers/ Stakeholders	Covington Lakes Homeowners, Covington Lakes HOA
Project Scenario & Context	The Covington Lake Subdivision off Carolina Forest Boulevard in Myrtle Beach, South Carolina, has 4 stormwater retention ponds. All water runoff from any street or the 147 lots in the development goes to the retention ponds. The purpose of these ponds is to slow and treat the runoff to prevent flooding and pollution downstream through storage, evaporation, sedimentation, infiltration, and controlled discharge over time. In addition, the lakes provide beauty, home for wildlife, and recreational fishing. The residents and the HOA Board recognize that maintenance of the lakes is a high priority to ensure that the water being stored and being sent down to the ocean/river is as pollution-free as possible. In addition, preservation of the pond depth through the control of erosion is important to maintain the storage capacity of ponds. During an HOA Board workshop on March 4, 2020, Total Lake, the contracted pond management company, reported that the condition of the ponds is quite good. The depth is, for the most part, 4 feet deep (required by Horry County). Total Lake reported that the lake bottoms generally had very little silt and were hard. Engineering design requirements for stormwater retention ponds are based on 25- and 100-year storms, but more frequent and intense storms have become increasingly common in the last few years. Thus, the current required depth might not be enough. Also, the ponds are decades old, and the depth might have changed over time. It is therefore important to determine the actual pond volume.
Problem Statement	The Covington Lakes Subdivision and its stormwater retention ponds were developed over 25 years ago, when the design code for ponds required storage for 25-year storms and 100-year storms were not enacted. Higher-intensity storms (e.g., 500-year events) are becoming more frequent. Moreover, the sedimentation and erosion may have reduced pond depth and subsequently total capacity. It is therefore necessary to assess the accurate volume of the ponds to inform future management decisions, ensure homeowners safety and peace of mind, and develop a community outreach plan to drive participation in protecting and preserving the ponds.
Design Statement	The Team has been tasked with surveying the stormwater retention pond adjacent to Carolina Forest Blvd. and Covington Lakes Dr.; provide AutoCAD drawings of pond; calculate pond's volume precisely; determine seasonal water levels (low water level, high water level, and normal water level); simulate pond levels during 10-year, 25-year, 50-year, 100-year, and 500-year storms; and create a community education and outreach plan to inform community members and drive participation in protecting and preserving the ponds.

Table 5. Project #4: Reducing Stormwater Impacts on Water Quality in Shellfish Harvesting Areas—A Pervious Pavements Installation Approach

Project Title	**Project #4: Reducing Stormwater Impacts on Water Quality in Shellfish Harvesting Areas—A Pervious Pavements Installation Approach**
Community Client/ Technical Advisor (s)	Public Works Department, City of North Myrtle Beach (Stormwater)
Target Consumers/ Stakeholders	City of North Myrtle Beach, Horry County and Surrounding Communities
Project Scenario & Context	In 2016, the SCDHEC funded the Waccamaw Regional Council of Government (COG) with a $21,000 grant to develop a watershed-based management plan. COG worked with North Myrtle Beach, Horry County, and Coastal Carolina University to evaluate bacteria levels from the Intracoastal Waterway to the beach in the Cherry Grove, Hog Inlet, Dunn Sound Creek and Little River Neck areas. Hog Inlet and Dunn Sound Creek are designated as Shellfish Harvesting Waters by the SCDHEC and are located within the Shellfish Program's Management Area 01; therefore, fecal coliform bacteria is the primary water quality standard monitored. In 2018, COG completed the plan, detailing several recommendations on how to control the bacteria with the end goal of increasing shellfish harvesting again. As a result, COG was awarded a 319 grant to implement the plan. Recommendation F-15 from the plan proposed the installation of pervious surface parking lots and streets throughout the watershed. The Client requested that the Team explore potential locations to install pervious pavement on the last 50–100 ft sections of each of the dead-end streets in the Cherry Grove Beach area. Targeted catchment areas are East Cherry Grove, Seas Mountain Highway, Hill Street, and Little River Neck Marsh.
Problem Statement	The 2017 Shellfish Management Area 01 Annual Update reveals that none of the monitoring sites met the standard for designated use. As of the SCDHEC's 2015 Annual Update report, all designated shellfish habitats within Management Area 01 are restricted or prohibited to shellfish harvesting. The watershed-based plan identified the sources of the fecal coliform impairments (e.g., stormwater runoff) and proposed strategies to help improve water quality in the Hog Inlet–Dunn Sound Creek area. The drainage system within the Cherry Grove Beach area does not have a conventional curb, gutter, and drainage ditch storm sewer system. Instead, during storm events, precipitation runs off as sheet flow across the landscape, particularly along impervious surfaces. More pervious pavement areas are needed to increase stormwater runoff infiltration into the ground surface prior to it reaching the estuary shoreline.
Design Statement	The Team is tasked with exploring potential locations to install pervious pavement on the last 50–100 ft sections of each of the dead-end streets in the Cherry Grove Beach area. The Team must identify/prioritize at least 3 site-specific locations within the Cherry Grove area to design, permit, and install areas of pervious pavement at the identified locations. The potential pervious pavement areas are not necessarily limited to street ends. The areas chosen for pervious pavement installation must be: (1) be owned and maintained by the city, and (2) receive and filter stormwater runoff to have a positive impact on water quality within Hog Inlet and Dunn Sound Creek. Targeted catchment areas are East Cherry Grove, Seas Mountain Highway, Hill Street, and Little River Neck Marsh.

Table 6. Project #5: Simultaneously Restoring a Windy Hill's Saltwater Marsh and Preserving Briarcliffe Acres' Freshwater Ponds—Stabilizing White Point Swash Approach

Project Title	**Project #5: Simultaneously Restoring a Windy Hill's Saltwater Marsh and Preserving Briarcliffe Acres' Freshwater Ponds—Stabilizing White Point Swash Approach**
Community Client/ Technical Advisor (s)	Public Works Department, City of North Myrtle Beach (Stormwater)
Target Consumers/ Stakeholders	North Myrtle Beach, Horry County, and Briarcliffe Acres
Project Scenario & Context	North Myrtle Beach, Horry County, and Briarcliffe Acres have been studying erosion, flooding, and poor water quality within the marsh and at the interface between the marsh, ocean, and freshwater pond system. The salt marsh experienced significant loss of marsh grass 2 years ago. Streets near the marsh experience flooding during high tide (King Tide) and during excessive rain events. Briarcliffe Acres experiences loss of the dune system along the beachfront to the extent that freshwater ponds are potentially exposed to ocean wash-over. Horry County periodically maintains the swash opening to the ocean, which requires substantial construction on the beach.
Problem Statement	Streets near the Windy Hill Marsh, a saltwater marsh, experience flooding during high tide (King Tide) and during excessive rain events. Flooding and erosion from surrounding roadways and developments cause freshwater and sediments to enter the saltwater marsh. Poor stability in the White Point Swash prevents saltwater from going up into saltwater Windy Hill Marsh, resulting in the dying out of marsh grass and critical habitats. The poor stability of the White Point Swash and the loss of Briarcliffe Acres dunes system increases the potential for ocean water wash-over into freshwater ponds. North Myrtle Beach, Horry County and Briarcliffe Acres need sustainable solutions to the flooding, erosion, poor water quality, and unstable swash and dune systems to preserve critical habitats and ecosystems of the Windy Hill saltwater marsh, as well as the freshwater pond system in Briarcliffe acres.
Design Statement	The Team has been tasked with proposing solutions (1) to street flooding near Windy Hill Marsh and associated water quality issues in the marsh; (2) to increase White Point Swash stability, subsequently allowing saltwater back into the marsh to reestablish marsh grass and ecosystem; and (3) to prevent saltwater from entering the freshwater pond over in Briarcliffe Acres.

Table 7. Project #6: Toward Developing a Watershed-Based Plan for Edisto Island

Project Title	**Project #6: Toward Developing a Watershed-Based Plan for Edisto Island**
Community Client/ Technical Advisor (s)	Department of Forestry & Environmental Conservation Clemson University Extension
Target Consumers/ Stakeholders	Citizens of the Town of Edisto Beach
Project Scenario & Context	The Edisto River Basin is the watershed for the Edisto River, one of the longest free-flowing blackwater rivers in North America. The lower part of the Edisto River Basin joins with the Ashepoo and Combahee River Basins to create the ACE Basin, an estuary of national significance. Land use across Edisto Island is mostly rural with low-density residential and agricultural activities predominating. The 3 sub-watersheds of focus—Store Creek, the South Edisto River-Atlantic Intracoastal Waterway, and the Dawho River-North Edisto River—span Edisto Island and the town of Edisto Beach and are part of the larger Edisto River Basin. The town of Edisto Beach, a 6-mile-long barrier island made up of approximately 25% salt marsh, is a beachfront community with a small population of full-time residents that experiences a seasonal influx of tourists; it also includes a 1,200-acre state park that hosts both cabins and campsites. Many of the waterways around Edisto Island and the town of Edisto Beach have high levels of bacteria that exceed safe levels for their designated use. There are 2 Total Maximum Daily Load (TMDLs) in place for bacteria, and around 24 sites are also on the 303d list for bacteria and/or sediment. Nearly 70% of the shellfish beds across the 3 sub-watersheds encompassing Edisto Island and Edisto Beach are closed to harvest.
Problem Statement	Waterways of the town of Edisto Beach and its surrounding watershed have pollution levels that exceed safe levels for designated use; there are 2 TMDLs in place for bacteria, around 24 sites are on the 303d list for bacteria and/or sediment, and nearly 70% of the shellfish beds are closed to harvest. The community needs to create a watershed-based plan for the Edisto Island Watershed that will provide a roadmap to help the community manage pollution problems, restore impaired water bodies (so that all users can enjoy both consumptive (shellfish and finfish harvest) and nonconsumptive (water-based recreation, scenic viewshed, wildlife viewing) uses, and sustainably implement practices to protect the overall health of the connected local and downstream watersheds, which combines to create the Ashepoo, Combahee, and Edisto River (ACE) Basin, an estuary of national significance.
Design Statement	The Team is tasked with the first 3 of 9 essential stages of developing a watershed-based plan for the Edisto Island Watershed. The Team is required to identify the primary sources of pollutants, identify potential management measures or best management practices (BMPs) to implement across the watershed, and estimate the pollution removal potential of installing those BMPs. Finally, due to budgetary constraints, the Team must provide a project prioritization and justification rubric to help community stakeholders decide on an implementation action plan. The recommendations provided as part of this project will inform the next 6 stages of the watershed planning process. Once the watershed-based plan is complete, projects identified in the plan may be eligible for EPA's 319 funds. The project's design brief is due by December 4, 2020.

Table 8. Project #7: Horry County Administration and Courthouse Building's Stormwater Detention Pond #4 Conversion to Raingarden

Project Title	**Project #7: Horry County Administration and Courthouse Building's Stormwater Detention Pond #4 Conversion to Raingarden**
Community Client/ Technical Advisor (s)	Horry County Government, Stormwater
Target Consumers/ Stakeholders	Horry County Government, Stormwater, Users of the Waccamaw River, Citizens in Horry County
Project Scenario & Context	When the Horry County Administration and Courthouse Building on 2nd Avenue and Laurel Street in Conway was constructed, large, dry stormwater detention ponds were built to control runoff from the parking lots and rooftops. These ponds, however, were not designed to address water quality. Horry County Stormwater has converted one of the dry detention ponds (Pond #3) into a large-scale rain garden to improve the quality of stormwater before it reaches the Waccamaw River. Some of the plants in the current retrofit have died out. The county wishes to convert a second pond (Pond #4) into a rain garden, implementing some of the lessons learned from the first intervention.
Problem Statement	Horry County and the users of the Waccamaw River need a stormwater management system that will collect rainfall runoff from the roofs and parking lots of the Horry County administration and courthouse building and must treat it before releasing it in less than 24 hours to the Waccamaw River. The current detention ponds were not designed for pollutant removal and allow untreated stormwater runoff to enter the Waccamaw River, which suffers from low dissolved oxygen and high bacterial levels during rain events and which is a drinking water source for the area.
Design Statement	Team Aqua-clina was tasked with proposing a design for a bioretention area that will utilize Pond #4 and limit ponding so that it does not generate mosquitoes and does not drown the plants. Standing water must drain from the rain garden in less than 24 hours. Selected plants must be able to survive the conditions in the bioretention area.

Table 9. Project #8: Bringing Green Back to the Coast

Project Title	**Project #8: Bringing Green Back to the Coast**
Community Client/ Technical Advisor (s)	Coastal Carolina University
Target Consumers/ Stakeholders	The Woods (at Coastal Carolina University) Student Housing's Residents and Visitors
Project Scenario & Context	The Woods Residence Halls were the first dorms on Coastal Carolina University's campus. They were opened in 1987 by Chancellor Ronald G. Eaglin. The community comprises 6 buildings (3 stories each), which are named after trees predominantly grown in the South: Cypress, Dogwood, Elm, Maple, Oak, and Palmetto. The dorms are coeducational housing for new and first-year students with a total occupancy of about 420. The Woods buildings do not have their own laundry facilities, so students must travel to Eaglin and Ingle Halls to wash and dry their clothes. Conway receives, on average, about 55 inches of rainfall annually with a mean monthly low and high of 3.24 inches and 7.5 inces in March and August, respectively. There are frequent storms and hurricanes particularly during the fall semesters. The front areas of the dorm buildings consist of wetland slough with associated tree canopy (e.g., Laurel Oak, Bald Cypress) and are frequently flooded even during low-intensity rain events. Residents and visitors must trek through water puddles to get to and from classes or find alternate and indirect routes to their destinations on campus. According to the institution's master plan, "the east-west ribbons of wetlands and associated woodlands remain and form a strong landscape character. These wetland areas should be preserved and enhanced: they play a key role in handling stormwater and they add a distinctive, authentic character and sense of place. . . . The University should build on the strong character of the spaces within Chanticleer Drive and improve the weaker courtyard spaces at the River residences and The Woods residences." The Team will propose a low-impact development solution as part of the Environmental Protection Agency's (EPA) Campus RainWorks Challenge— Green Instructure Design Competition.
Problem Statement	Residents and visitors to the Woods Dorms at Coastal Carolina University have complained about flooding of the areas adjacent to and in front of the dorms. Students must trek through water and step over large puddles to get to and from their classes and laundry and cafeteria facilities. A bioretention system is needed to control stormwater runoff from the roofs and other pervious surfaces of the dorm while improving the weaker courtyard spaces.
Design Statement	The Team has been tasked with proposeinga low-impact development solution to the flooding challenges at The Woods Residence Halls on the Coastal Carolina University campus. Per the criteria outlined in the EPA's Campus RainWorks Challenge—Green Instructure Design Competition, the design area must cover no more than 15 acres, can be built within a reasonable time frame, and should offer one or more local stormwater management solutions that provide multiple environmental, economic, and social benefits.

Table 10. Project #9: Lincolnshire Community Drainage Improvement Study & Design

Project Title	**Project #9: Lincolnshire Community Drainage Improvement Study & Design**
Community Client/ Technical Advisor (s)	Department of Public Works, Georgetown County
Target Consumers/ Stakeholders	Lincolnshire community members, SCDOT, SCDHEC & Georgetown County's Department of Public Works
Project Scenario & Context	The Lincolnshire Community is located approximately 2.5 miles west of the city of Georgetown, off Highway 521 (Highmarket Street) toward the city of Andrews. It is bounded by County Rd S-22-718 on the north, Whites Creek Rd on the east, Greentown Rd on the west, and Highway 521 or Highmarket Street on the south. The community encompasses approximately 60 acres of residential homes and secondary roads. Upon preliminary site inspection and review of the existing drainage system serving the community, it was determined that the entire community depends upon backyard drainage ditches to convey runoff from the roads and properties to the ultimate receiving water body—Whites Creek. The field reconnaissance determined that little or no maintenance (i.e., litter removal, grading, mowing) of the backyard ditches has been done. Therefore, there is no drainage connection from the community to the outfalls (outfalls close to Amelia Dr & Friendfield St and close to County Rd S-22-718 & Whites Creek Rd). Unfortunately, what little roadside drainage system exists is in bad condition, if working at all. This lack of maintenance has led to the deterioration of the roadbeds. Potholes and alligator cracking in roads are abundant. Standing water on the road and in roadside swales that are not connected to the backyard ditches is common as well, creating a mosquito nuisance.
Problem Statement	The residents of the Lincolnshire community in Georgetown, South Carolina, experience frequent flooding and property damage, even during 2-year storm events, and poor roads as a result of inadequate and/or failing and poorly maintained drainage systems. The community needs proper drainage as well as community empowerment, outreach, and educational programs to disincentivize littering; to prevent future floods and subsequent property damage, and to avoid further damage to roads and disease outbreak as a result of mosquito infestation.
Design Statement	CHK Engineering has been tasked with preparing a small drainage study of the Lincolnshire community, which includes development of a flow rate for the drainage area to design a ditch or pipe size for the downstream end (outfall) of the system. All assumptions with justifications must be stated. An attached Lincolnshire Drainage field inspection map is to be used to delineate the limits of the drainage area. Highway 521 should be considered the downstream end point, McDonald Rd is the northeast boundary, and Missroon St (County Rd S-22-685) is where the backyard properties may drain into as the northwest boundary. The GTC GIS contour layer must be used to determine this boundary and state their case. The Team must also prepare an innovative and creative educational and outreach program for litter control/removal for this specific community.

DISCUSSION AND RECOMMENDATIONS

This project provided benefits both to the students and the community. The projects were linked to the course and program outcomes, thus extending the students' learning experiences beyond the classroom. Students' feedback on the course included:

- "enjoyed being able to have open discussion while working on real-world projects";
- "great experience to be able to work within a group";
- "I enjoyed using real-life situations and actually being able to solve a problem that involves our community. It made it more interesting for me and challenged me this semester. I broke a lot of barriers this semester by presenting frequently and doing lots of research"; and
- "project was very fun and gave a good insight to being an engineer. I enjoyed it thoroughly."

About 50% of the students in the Engineering Program at Coastal Carolina University identify as underrepresented minorities. The ENGR 199/299 Cohort Grant Challenge Cornerstone Course Sequence is a curriculum requirement for all majors. These hands-on, experiential, community-based opportunities have been shown to be high-impact practices that broaden participation and increase retention in engineering programs. The initial partnership between the Engineering Program and CWSEC was very successful; it met and exceeded its objectives. Students learned about our planet's grand challenge of providing clean water, the impact stormwater has on the urban water cycle, and their abilities to contribute to solving this challenge using their engineering design skills. Additionally, students practiced meta-skills such as design, research, written and verbal communication, and client management. The next steps include: continue to engage consortium members and students on realistic, real-world problems; engage students on similar projects in other courses such as Senior Design; and facilitate more fieldwork when it is safe to do so. Additionally, formative and summative assessments of ABET student outcomes will be included in future studies.

ACKNOWLEDGMENTS

Special and heartfelt thanks to the member organizations and persons in the CSWEC for assisting in the realization of these projects.

REFERENCES

ASEE. 2012. Going the distance: Best practices and strategies for retaining engineering, engineering technology and computing students. Washington, DC: American Society for Engineering Education.

Blair A, Sanger D, Lovelace S. 2016. Stormwater runoff in watersheds: A system for predicting impacts of development and climate change. In: Stringer CE et al., eds. Headwaters to estuaries: Advances in watershed science and management—Proceedings of the Fifth Interagency Conference on Research in the Watersheds. March 2–5, 2015, North Charleston, South Carolina. e-Gen. Tech. Rep. SRS-211. Asheville, NC: US Department of Agriculture Forest Service, Southern Research Station.

Chang JC. 2002. Women and minorities in the science, mathematics and engineering pipeline. ED467855 2002-06-00. Los Angeles, CA: ERIC Clearinghouse for Community Colleges.

Dickes LA, Allen J, Jalowiecka M, Buckley K. 2016. A policy lens of south carolina coastal stormwater management. Journal of South Carolina Water Resources. 3(1):5.

Ellis KK, Callahan T, Greenfield DI, Sanger D, Robinson J, Jones M. 2017. Measuring and modeling flow rates in tidal creeks: A case study from the central coast of south carolina. Journal of South Carolina Water Resources. 4(1):4.

Freeman LA, Corbett DR, Fitzgerald AM, Lemley DA, Quigg A, Steppe CN. 2019. Impacts of urbanization and development on estuarine ecosystems and water quality. Estuaries and Coasts. 42(7):1821–1838.

Gold AC, Thompson SP, Piehler MF. 2017. Water quality before and after watershed-scale implementation of stormwater wet ponds in the coastal plain. Ecological Engineering. 105:240-251.

Gray M, Lundy C. 2016. Implementing and integrating international research into the engineering curriculum at Lincoln University, Pennsylvania and the University of the West Indies, Trinidad. Paper presented at the 2016 ASEE International Forum. ASEE PEER; New Orleans.

Horry County Government. 2019. Imaging 2040—comprehensive plan ordinance #54-19. Horry County Government. https://www.horrycounty.org/portals/0/docs/PlanningandZoning/Imagine2040/IMAGINE%202040_compressed.pdf.

Kuhl H. 2019. Stormwater and tidal hydraulics in an urban coastal watershed: Land use change impacts. Water. 11: 2369.

Ma Y, Hao S, Zhao H, Fang J, Zhao J, Li X. 2018. Pollutant transport analysis and source apportionment of the entire non-point source pollution process in separate sewer systems. Chemosphere. 211:557–565.

Mallin MA, Burkholder JM, Cahoon LB, Grogan AE, Sanger DM, Smith E. 2019. An environmental assessment of the north and south carolina coasts. World seas: An environmental evaluation. Elsevier. 405–426.

NAE. 2021. National Academy of Engineering, grand challenges for engineering in the 21st century. http://www.engineeringchallenges.org/challenges.aspx.

NSF. 2019. Women, minorities, and persons with disabilities in science and engineering. Arlington, VA. No. 19-304.
Pines D. 2005. NPDES Phase II Stormwater Rule–an excellent opportunity to get students involved in a service learning project. age. 10:1.
Schroer WF, Benitez-Nelson CR, Smith EM, Ziolkowski LA. 2018. Drivers of sediment accumulation and nutrient burial in coastal stormwater detention ponds, South Carolina, USA. Ecosystems. 21(6):1118–1138.
Shukla AK, Ojha CSP, Mijic A, Buytaert W, Pathak S, Garg RD, Shukla S. 2018. Population growth, land use and land cover transformations, and water quality nexus in the upper Ganga River basin. Hydrology and Earth System Sciences. 22(9):4745–4770.
US EPA. 2005. Stormwater Phase II final rule: An overview. In: Office of Water, editor, United States Environmental Protection Agency.
Yang YY, Toor GS. 2018. Stormwater runoff driven phosphorus transport in an urban residential catchment: Implications for protecting water quality in urban watersheds. Sci Rep. 8(1):11681.