STORM WATER OUTFALL STUDY

HORRY COUNTY BEACHES

FOR

HORRY COUNTY, SOUTH CAROLINA

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DAVIS & FLOYD, INC. JOB NUMBER 11298.00

PREPARED BY

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ENVIRONMENTAL DIVISION

GREENWOOD, SOUTH CAROLINA

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EXECUTIVE SUMMARY

During the past several years, beach closings in Horry County, as well as most other coastal areas in the country, have resulted due to high levels of bacterial contaminants being detected in the surf. These high levels of contaminants seem to correlate with heavy rainfall. In an attempt to identify options for improvement to water quality at storm water outfalls that discharge to the ocean in the unincorporated limits of Horry County, Davis & Floyd, Inc. was retained to evaluate the situation. During the late spring and summer of 2000, Davis & Floyd, Inc. conducted a study of surface water run-off and discharge to the surf in the unincorporated areas of Horry County. The initial scope of the study was to collect background information from state and local government sources and develop a sampling and analysis strategy through which the area discharges to the surf could be evaluated. It was anticipated that the results of the initial sampling and analysis would identify specific areas of concern and that further study would be conducted on these areas to determine the source and/or sources of contamination. During this phase of the project, ten (10) dry weather flow sampling locations and thirteen (13) additional wet weather flow sampling locations were evaluated. The results of this initial work demonstrated that all of the discharges to the surf were contaminated with coliform bacteria all the time. Therefore, after consultation with Horry County officials, it was decided that the remaining study efforts would focus on two (2) specific areas. The areas chosen were the drainage area to outfall HCSBD01, a campground in the Surfside Beach area, and drainage area HCLAD06, a residential area in the Lake Arrowhead area.

During the study, a number of site-specific investigations were undertaken. The results of these investigations demonstrate that the problem of surf contamination with enterococcus bacteria is wide spread. The study results document the adverse effect of storm water run-off on surf water quality and identifies a number of area specific problems, such as lagoon sediment, sewer overflows, drainage problems, septic tank malfunctions, animal waste, and point source discharges, that contribute to the overall problem.

A number of recommendations for immediate actions designed to either directly address and/or further define site specific problem areas are presented in this report. These actions fall into the general categories of:

- Administrative actions
- Design/construction projects
- Additional investigations

The administrative actions that are recommended include the institution of public notification, education, and awareness programs that deal with the sources of contamination and how the general public can help eliminate and/or minimize some of these impacts to avoid beach closings. Additional administrative actions that should be considered include the passage of ordinances that deal with sources of contamination.

A sewer system feasibility study is needed for the Braircliff Acres area and any other areas primarily served by septic tank systems. It may be necessary to construct sewer systems in these areas. A second such project is to perform Infiltration/Inflow studies in areas prone to flooding, and further, to undertake corrective actions to solve problems identified.

The final category of actions involves further investigations to:

- verify hypotheses developed during this study, but not included in the original scope of this project
- evaluate the feasibility of possible corrective actions to problems identified in this study, such as approaches to address contamination in the multitude of ponds in the area, and the possibility of piping the storm water discharges to the ocean bottom or to the Intracoastal Waterway, etc.

1.0 INTRODUCTION

The purpose of this document is to report the findings of a study, commissioned by Horry County, South Carolina, on the water quality of the storm water outfalls discharging to beaches in the unincorporated areas of Horry County. The main objective of the study was to identify sources of contamination and to recommend options for improvement to water quality at storm water outfalls within the study area. The unincorporated areas include Garden City, the area between the Town of Surfside Beach and Myrtle Beach, the area between Myrtle Beach and North Myrtle Beach, and areas north of North Myrtle Beach. This study focused on two of these areas, including the Surfside Beach area (SB) between the Town of Surfside Beach and Myrtle Beach and the Lake Arrowhead (LA) area between Myrtle Beach and North Myrtle Beach. Storm water in Garden City primarily drains into Murrells Inlet. Garden City was not included in the study because no outfalls, such as pipes, ditches, or swashes, were identified along the beach. As directed by Horry County, the area north of North Myrtle Beach was not included in the study.

According to the United States Environmental Protection Agency (EPA), nearly 4,000 beach closings and swimming advisories were issued around the United States for oceans, bays, and the Great Lakes by state and local governments in 1995. The majority of beach closings were due to indications of the presence of high levels of bacteria in the surf. In 1997, EPA initiated the BEACH Watch program to help states ensure public health and safety at beaches and all recreational waters. Horry County began monitoring its beaches, on a weekly basis, during the summer in 1997. The monitoring data seemed to indicate that high levels of bacteria detected in the surf were associated with rain events. This observation is typical of that observed for most beaches throughout the country.

The South Carolina Department of Health and Environmental Control (SCDHEC) recently began monitoring the surf for bacteria on a regular basis and after rain events. Local governments in the beach areas of Horry County have agreed with a request by SCDHEC to post warning signs that advise swimmers when high levels of bacteria are detected in the surf.

The general approach of this study was to utilize a phased investigation. The first phase was to identify storm water discharge points (outfalls), the drainage area contributing to each outfall, and notable activities within the drainage area. The discharges at these outfalls were monitored to identify outfalls that contribute the highest levels of bacteria, measured as enterococci, to the surf. As a part of this study, existing bacteria contamination data was compiled and reviewed (See Appendix B). Selected drainage areas that result in storm water flows to the outfalls, and which were found to be significantly contributing to the elevated enterococcus counts in the surf, were studied in more detail. This was done in an effort to locate the source(s) of the contamination and to identify strategies for dealing with the contamination.

The appendices are provided as backup information for this study. Appendix A contains all data collected during this study from routinely sampled locations.

1.1 Identification of Outfalls

Outfalls within the study area were identified by reviewing aerial photographs, USGS topographic maps, and topographic information from Horry County's GIS system, followed by on the ground inspection of the entire beach area included in the study. Each of the outfalls was then assigned a unique identification number.

The sampling site identification number (ID) was developed using the following descriptive letters and numbers:

- Each site ID has the prefix of (HC) for Horry County.
- The next two letters identify the area, which is either the Surfside Beach area (SB) or the Lake Arrowhead area (LA).

- The letters identifying the area are followed by either a (D) for sites which can be sampled in dry weather or a (W) for sites which can only be sampled during wet weather. Samples that are labeled with a (S) are for soil samples.
- The sites are usually numbered going south to north with two digits such as 01, 02 and so forth.
- The two digit numbers are followed by a dash and the last two additional digits where (00) indicates the outfall at ocean. Sites ending with numbers other than (00) such as 01, 02 and so forth indicate that the site is located within the drainage basin that drains to the outfall at (00). Within drainage basins, the last two digits are normally arranged such that the smaller numbers are located closest to the outfall (00) and the larger numbers are progressively further away from the outfall.

Each of the outfalls is identified by its site ID number on the aerial photographs found in Appendix C. The outfalls and sample locations are also shown on the drawings found in Appendix E. The photos found in Appendix D depict each of the outfalls and many of the other sampling points, as well as other subjects of interest. A list of the site ID numbers and the site description is as follows:

Site ID	**Site Description**
HCSBD01-00	Swash at south end of Ocean Lakes Campground (CG)
HCSBD02-00	Drainage pipe at north end of Ocean Lakes CG
HCSBD03-00	Swash between Lakewood Campground and Pirateland CG
HCSBD04-00	Swash south of pier in Myrtle Beach State Park
HCSBW01-00	Drainage pipe closest to Sand Dollar Drive at southern end of Ocean Lakes
HCSBW02-00	Pipe at Seaside Drive near lot 1102 at southern end of Ocean Lakes CG
HCSBW03-00	Pipe at Seaside Drive near lot 1038, just south of swash in Ocean Lakes CG
HCSBW04-00	Pipe at Seaside Drive near Live Oak Road in Ocean Lakes CG
HCSBW05-00	Pipe at Seaside Drive near Coral Drive in Ocean Lakes CG
HCSBW06-00	Pipe at Seaside Drive near Sections E and HH in Ocean Lakes CG
HCSBW07-00	Pipe at Seaside Drive near Sand Dune Drive in Ocean Lakes CG
HCSBW08-00	Pipe at Seaside Drive near Shell Drive in Ocean Lakes CG
HCSBW09-00	Pipe at Seaside Drive near Salt Works Road in Ocean Lakes CG
HCSBW10-00	Pipe at Seaside Drive closest to Lot 2119 in Ocean Lakes CG

Site ID	Site Description
HCSBW11-00	Wash out by the pool at Lakewood
HCLAD01-00	Singleton Swash south of Ocean Annie's beside Shore Drive
HCLAD02-00	Drainage pipe at north end of Kingston Plantation, south of Wyndham
HCLAD03-00	Black corrugated pipe, just north of the Wyndham
HCLAD03-01	Water pouring out of the air conditioner
HCLAD04-00	Drainage pipe from complex, north of Wyndham
HCLAD05-00	Drainage pipe at northern end Myrtle Beach Travel Resort and south of Lands End Resort
HCLAD06-00	Swash at bridge between beach at Briarcliff Acres
HCLAW01-00	Drainage pipe for yard and parking just north of the Wyndham
HCLAW02-00	Drainage pipe in seawall for complex north of the Wyndham
HCSBD01-01	Swash in Ocean Lakes CG, shore side of bridge on Seaside Drive
HCSBD01-02	Sand Dollar Lake, just before water enters swash at
HCSBD01-03	Southern most end of Sand Dollar Lake at concrete gutter
HCSBD01-04	Swash at north side of bridge on Live Oak Drive
HCSBD01-05	Swash at north side of bridge on Coral Drive, lower end of Magnolia Lake
HCSBD01-06	Drainage course behind snack bar in Ocean Lakes CG
HCSBD01-07	Southern end of Ocean Lakes, corner of E. Lake Trail & Ocean Lakes Drive
HCSBD01-08	Northern Side of bridge off Coral Drive at the top of Magnolia Lake
HCSBD01-09	Southern most end of Sandlapper Lake at Ocean Lakes Drive
HCSBD01-10	Upper end (west) of Magnolia Lake, pipe at Spring Lane
HCSBD01-11	PVC pipe (~4"dia.), flowing into swash, south of bridge on Live Oak Road
HCSBS01-00	Beach house B12 (soil)
HCSBS01-01	Swash in Ocean Lakes GC, south of Live Oak Road (soil)
HCSBS02-00	Beach house B2 (soil)
HCSBS03-00	Lot 2089 (soil)
HCSBS03-01	Lot 2068 (soil)
HCSBS03-02	Lot 2075 (soil)
HCSBS03-03	Beside lot 3022 (soil)
HCSBS04-00	Swash at bridge, south of pier in Myrtle Beach State Park (soil)
HCSBS04-01	Upstream of swash in Myrtle Beach State Park, by the pond (soil)

1.2 Rain Gauge Locations

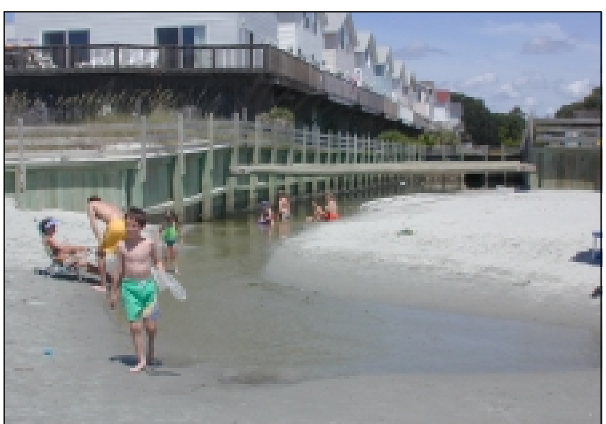
Rainfall data was collected throughout the project at three separate rain gauge locations. A rain gauge was located in the northern section of Myrtle Beach State Park. Myrtle Beach State Park is located between the beach and US 17, just north of Surfside Beach and just south of Springmaid Beach. Springmaid Beach is located at the southern tip of Myrtle Beach. This gauge was mounted on the ground in a clearing near the park maintenance area approximately 1,500 feet from the ocean. A second rain gauge was located on the rooftop of the Wyndham Hotel. This beachfront hotel is located in an area near Lake Arrowhead Campground, just north of the Kingston Plantation. The third rain gauge was mounted on the ground in the yard beside the Davis & Floyd, Inc. Mobile Environmental Laboratory, which was parked inside the fenced Horry County Maintenance Facility located at 1282 Howard Parkway. The building at this site is referred to as Building Number 516 within the South Park Village, formerly the Myrtle Beach Air Force Base.

Rain gauge at Davis & Floyd Mobile Lab

1.3 Identification of Drainage Areas

This section of this report describes each of the major drainage areas located within the overall study area. Reference is made to the maps in Appendix M, which show the approximate boundary of each drainage basin.

The drainage basin (HCSBD01) that discharges to the ocean at Outfall HCSBD01-00 flows through an unnamed swash at the southern end of Ocean Lakes Campground. The drainage basin, which covers approximately 470 acres, includes a large portion of the campground, a section of Highway 17, Deerfield Plaza, a portion of Deerfield Plantation, and several commercial properties. The width of the swash near the beach is approximately 20 feet. Flow



Outfall HCSBD01-00

during non-rain events covers a smaller section of the channel approximately 7 feet wide and 5 inches deep. The flow during non-rain events is estimated to be approximately 5 cubic feet per second (approximately 3,230,000 gallons per day).

The drainage basin (HCSBD02) that discharges through an 18” corrugated metal pipe to the ocean at Outfall HCSBD02-00 covers approximately 110 acres. It includes the northern portion of Ocean Lakes Campground and Myrtle Beach Resort up to a section of Highway 17. The flow during non-rain events is estimated to be approximately 1 cubic foot per second (650,000 gallons per day).

The drainage basin (HCSBD03) that discharges to the ocean at Outfall HCSBD03-00 flows through an unnamed swash that passes through the northern end of Lakewood Campground and the southern end of Pirateland. The drainage basin includes most of both campgrounds, Long Bay Estates, a section of Highway 17, several commercial properties along Highway 17, and a portion of Prestwick Golf Course and several other residential communities on the west side of Highway 17 around Lakewood and Woodland Park Schools. This drainage basin is made up of approximately 930 acres. The width of the swash near the beach is approximately 24 feet. Flow during non-rain events covers the entire channel approximately 10 inches deep. The flow during non-rain events is estimated to be approximately 35 cubic feet per second (22,620,000 gallons per day).

The drainage basin (HCSBD04) that discharges to the ocean at Outfall HCSBD04-00 flows through an unnamed wet weather swash in the center of Myrtle Beach State Park. The drainage basin, which covers approximately 120 acres, includes a large portion of the State Park, a section of Highway 17, and possibly a small residential portion of the Myrtle Beach Air Force Base.

Often, flow to the sand is so low that it stops at the edge of the dunes or seeps into the beach before reaching the surf.

The drainage basin (HCLAD01) that discharges to the ocean at Outfall HCLAD01-00 flows through Singleton Swash, which is located just north of the northernmost portion of Myrtle Beach. This large drainage basin, roughly 890 acres, includes several golf courses, including the Dunes and Arcadian Shores, various condominium and villa resort properties, as well as commercial properties, several lakes, Buck Island Swamp, the western portion of the Meher Spiritual Center, and drainage from approximately three miles of Highway 17. The width of the swash near the beach is approximately 30 feet. Flow during non-rain events covers the entire channel and averages 18 inches deep. The flow during non-rain events is estimated to be greater than 120 cubic feet per second (77,553,000 gallons per day).

The drainage basin (HCLAD02) that discharges to the ocean at Outfall HCLAD02-00 flows through a concrete pipe at the northern end of Kingston Plantation. The location of this outfall could also be described as being just south of the Wyndham Hotel parking lot. This drainage basin, which covers approximately 170 acres, includes a portion of the various hotels, condominium and villa resort properties, and Lake Arrowhead within Kingston Plantation between Kings Road and the ocean. Non-storm water flow to the beach is estimated to be less than 3 cubic feet per second. The dry weather flow is often so low that it pools at the end of the pipe on the sand and seeps into the beach before reaching the surf. This outfall and associated ponds were sampled previously by the U.S. Geological Survey. The results of those sampling events are found in Appendix B.

The discharge to the ocean at Outfall HCLAD03-00 is actually a large roof drain from the Wyndham Hotel. This very small drainage basin (HCLAD03), which discharges through a black plastic pipe just north of the hotel, includes the entire roof and a portion of the grounds surrounding the hotel. Peak non-storm water flow to the beach is estimated to be less than 5 gallons per minute. The flow is so low that it seeps into the sand before reaching the surf.

The drainage basin (HCLAD04) that discharges to the ocean at Outfall HCLAD04-00 flows through an 18-inch concrete pipe that receives flow from a community of homes, condominiums and villa resort properties located between Kingston Plantation and Myrtle Beach Travel Resort. This roughly 65-acre drainage basin is also located between Kings Road and the ocean and includes House Pond. Non-storm water flow to the beach is estimated to be less than 2 cubic feet per second. The dry weather flow is often so low that it pools at the end of the pipe on the beach and seeps into the sand before reaching the surf.

The drainage basin (HCLAD05) that discharges to the ocean at Outfall HCLAD05-00 flows through a concrete pipe at the northern end of Myrtle Beach Travel Resort (Campground), which is just south of Lands End Resort. This drainage basin receives flow from approximately 140 acres including condominium and villa resorts properties and the Myrtle Beach Travel Resort. This area also includes Chapin Pond between Kings Road and the ocean. Non-storm water flow to the beach is estimated to range from no flow to less than 3 cubic feet per second. The dry weather flow is often so low that it pools at the end of the pipe on the beach or seeps into the sand before reaching the surf.

Two drainage basins (HCLAD06) covering approximately 890 acres discharge to the ocean through White Point Swash. As directed by Horry County, the drainage basin from the north end of White Point and Prices Swamp Run was not sampled. The southern drainage basin that discharges to the ocean through White Point Swash was sampled from the unnamed swash, between the beach and Beach Drive, below the bridge to the Briarcliff Acres Beach Access area across from Palmetto Lane. This sample location, labeled HCLAD06-00, receives flow from a large area, which includes the eastern portion of the Meher Spiritual Center, the Briarcliff Acres residential community including Long Pond and Alligator Pond before it merges with the other drainage basin. The width of the swash varies up to 15 feet. Flow during non-rain events covers the bottom of the channel and averages 8 inches deep. The flow during non-rain events is estimated to be less than 40 cubic feet per second (25,850,000 gallons per day).

2.0 STUDY/INVESTIGATION

In an effort to better understand beach conditions with respect to enterococcus contamination, Horry County gathered information generated by the County and others over the past two years to be used as a data base for this study. Davis & Floyd, Inc. received and reviewed the information from the County prior to the initiation of field activities. The background information reviewed is presented herein as Appendix B and consists of the following:

- December 21, 1998, the Water Resources Division of the U.S. Geological Survey report of the results of two sampling events in Lake Arrowhead located in the Kingston Plantation area. Both sampling events included eleven sites and occurred on July 14, 1998 and September 3, 1998, respectively.
- Horry County surf monitoring data since 1997. Beginning in 1997, Horry County performed surf monitoring on a weekly basis at ten sites along the Horry County beaches. Personnel and students from Coastal Carolina University performed this monitoring program from May to September in 1997, 1998 and 1999.

After a review of the existing data, the overall study scope strategy was refined. As a part of the refined strategy, initial investigations focused on the identified dry weather discharges to the surf in the study area. After consideration of the data generated during the initial work, the strategy then focused on the areas identified as exhibiting significant enterococcus contamination. With this approach as a basis, study findings were used to define further activities and the database was built on facts as developed.

2.1 Findings

The data and related information resulting from this study are discussed and presented in the following sections.

2.1.1 Weather Information (Rain & Wind Data)

Rainfall and storm water runoff has long been associated with surf contamination. Therefore, Davis & Floyd, Inc. monitored rainfall at three locations during this project to develop data that could be used to correlate rainfall amounts and/or intensity with contamination levels. The rain gauge locations were as described earlier in this report. The project rain gauges collected data from the time of installation on May 30, 2000 until July 10, 2000. For the periods before and after the rain gauges were operational, rain data was retrieved from the National Oceanic and Atmospheric Administration (NOAA) for the Myrtle Beach Area for use in the study. An overlay of the daily rainfall measured in inches is shown in a graph at the top of each of the specific outfall graphs in Appendix F.

In addition to rainfall impact on contamination, during the study, we observed what appeared to be a correlation between heavy winds and contamination of the dry weather discharges. Therefore, studies were undertaken to see if wind velocity and/or direction could be a factor in raising the bacteria levels at outfalls during non-rain events. As a part of this, the daily wind information for the Myrtle Beach Area was obtained from NOAA. The daily velocities were graphed and overlaid over the graphs showing the daily enterococcus bacteria concentrations at the top of each of the specific outfall graphs found in Appendix G.

2.1.2 Monitoring During Dry Weather

Davis & Floyd, Inc. began monitoring ten outfalls to the beach that could be sampled during dry weather on May 16, 2000. This monitoring continued through the end of July 2000. The results of this work are presented in Appendix A.

The results of the enterococcus bacteria concentration for each of the outfalls during dry

Dry Weather Sampling @ HC SBD02-00

weather varied substantially. A total of 89% of the samples collected during dry weather resulted in less than 2,000 colonies/100ml. As a result, 11% of the dry weather sample results were greater than 2,000 colonies/100 ml. It was noted that the higher colony counts occurred for at least one outfall on 21 separate days. A large number of those occurrences took place on 5 days when the average wind speed exceeded 12 miles/hour and no rainfall was recorded. The 5 windy days were May 16, May 31, and June 14, 15, and 16, 2000. It was noted that people play, splash around and otherwise cool off in this and all other swashes observed on the beach. (See photo on page 1.5.) This was observed even though, as a result of this study, warning signs were posted advising the public that the water in the swash may contain high concentrations of bacteria.

A review of the dry weather enterococcus data demonstrates that the bacteria concentrations measured at the ten locations range from 0-colonies/100 ml to greater than 2,400-colonies/100 ml. It is possible to dilute the sample and measure the results of the enterococcus bacteria greater than 2,400-colonies/100 ml as was done on several occasions. Samples may be diluted prior to analysis in order to determine an actual concentration when the result is expected to be greater than the maximum generally reported. Some of the data presented in the table in Appendix A may show some results in this way. Each Appendix F graph presents the results for each separate outfall for the date sampled.

2.1.3 Monitoring During Rain Events

The outfalls were also sampled during and just after rainfall events. In Appendix A, the corresponding rainfall data is overlaid at the top of each graph of in enterococcus concentrations. As expected, approximately 80% of the samples collected during rain events resulted in enterococcus bacteria concentrations that exceeded 2,000-colonies/100 ml. Several graphs for each of the dry weather outfalls are found in Appendix J. The graphs present the enterococcus results for each outfall on May 24th and the morning of the May 25th before a rain event. A rain event began on May 25, 2000 and continued through the morning of May 26, 2000. The rainfall event was characterized by periods of light precipitation intermixed with periods of heavy rain. The total rainfall accumulation for this event, according to records obtained from NOAA, was just under one (1) inch (0.90 inches). Noted during the study period was that beach erosion was apparent after heavy rainfall events. The adjacent photograph is a demonstration of the erosion that was observed on May 26, 2000 after the rainfall event described above. The photograph clearly indicates that a significant amount of sand was lost during the rainfall and subsequent surface water runoff. In addition, the graphs present the results during the May 25th rain event and on the day after. The final graph is for May 29th, several days after the rain event.

Flooding Near HC SBD01-00 during Rain Event

Beach Erosion after Rain Event North of HC SBD02-00

2.1.4 Monitoring Within Drainage Areas

After several weeks of collecting samples at each of the outfalls that could be sampled during dry weather, it was determined that sampling should be focused within a specific selected drainage area. As a result, a total of eleven sampling locations was selected within the drainage basin that discharges to outfall HCSBD01-00 (basin HCSBD01). This drainage basin was chosen because it contained elements indicative of the entire study area. The sampling points were chosen in locations where changes in bacteria counts were anticipated, such as pond inlets and outlets. A total of eight samples was collected from each of the locations HCSBD01-01 through HCSCD01-10 during the period May 25th to June 8th, with only four samples collected at HCSBD01-11. The results of this work are presented in Appendix L. A review of the data indicates that enterococcus concentrations for HCSBD01-01, HCSBD01-02, HCSBD01-08, and HCSBD01-10 on May 31st were 2,419.2 colonies/100 ml or greater. Each of these sample locations would be considered to be part of the main path for the swash through the campground.

Sample Location SB D01-02

2.1.5 Enterococcus Bacteria in Soil Samples

As noted in the previous section, significant enterococcus concentrations were detected in the water samples collected within drainage basin HC-SBD01-00. Additionally, high concentrations were detected in all outfalls during rain events. In an effort to understand more completely the potential sources of this enterococcus, consideration was given to the part that soil contamination may play in the overall result observed. At least two sampling events occurred during rain events within the first month of the study. All of the samples collected from the eleven outfalls that could only be sampled during rain events exceeded the maximum of 2,419.2 colonies/100 ml. This raised the question of whether or not bacteria could be found anywhere at the ground surface.

On June 21 – 22, 2000, studies were conducted on soil samples located within basin HCSBD01 to determine the level of enterococcus present in the soils. The first four sample locations were chosen at random. The storm water pipe that led through the primary dunes, located at the corner of North Sand Dune Drive and Seaside Drive, was used as a reference. Beginning at a point farthest away from the beach, samples were collected along a line that extended perpendicular to Seaside Drive along North Sand Dune Drive toward the ocean and Seaside Drive. The first sample collected was at the corner of Campsite Number 2075. The second sample was collected at Campsite 2068. A third sample was taken at Campsite 2073, this due to suspicious appearance of the soil (wet and compacted, as if something had been emptied there). At the end of this row, directly across from the storm water pipe on Seaside Drive, a sample was collected on the corner of Campsite 2089. Two additional samples were taken in front of the oceanfront beach houses. One was directly across from House B12 on Seaside Drive. A second was across from House B2, in front of the storm water pipe.

Ten grams of sample were weighed out and mixed with 140 milliliters of sterile de-ionized water. This sample was placed in a column packed with about two inches of glass wool to serve as a filter for the sediment. It was found that the filter retained around 40 ml of water, with 100 ml needed for the test, therefore making it necessary to choose a beginning volume of 140 ml. An Enterolert® test was then conducted on the 100 ml of filtrate for each sample. The columns were cleaned with deionized water and methanol between samples. A beginning blank was run to prove that initial contamination did not exist in the column and that the water and other materials used did not contribute to the source of contamination. The results of this activity are presented in Table 2.1.

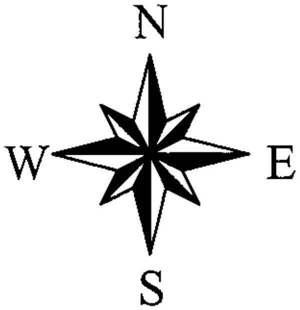
Further testing was conducted in HCSBD01 on July 11 – 12, 2000. This work was conducted to corroborate the previous investigation. The scope was expanded to grow fecal streptococci in order to differentiate the source of contamination. Several additional sites were added within the campground, as well as two sites in the State Park (HCSBD04). An Enterolert® test was simultaneously conducted, to correlate with the prior sampling.

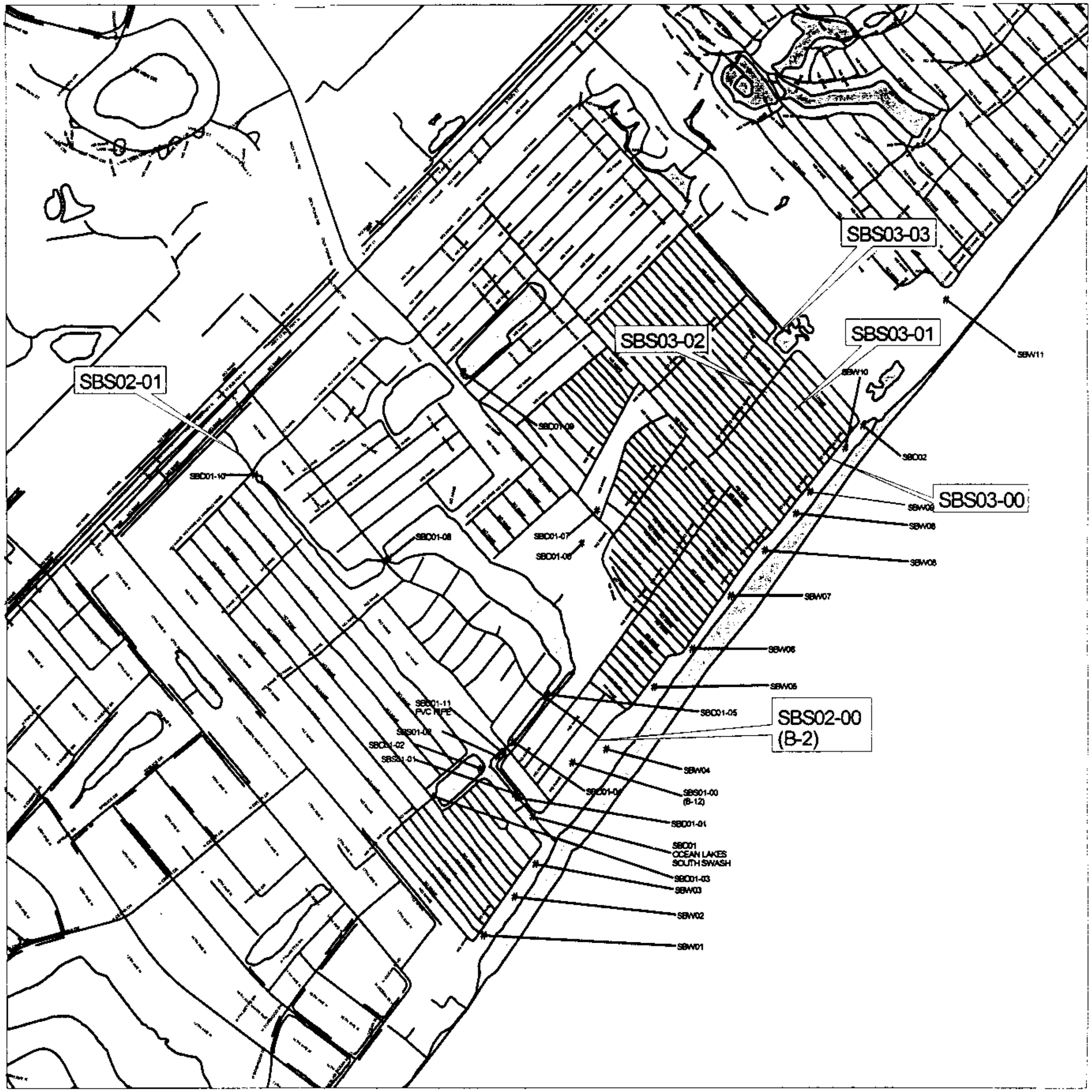
Soil samples were collected at each site. Each sample was prepared by weighing out 10 grams of sample and then mixed with 240 milliliters of sterile deionized water. The sample was filtered though a glass column containing a packing of around two inches of glass wool. Two samples of 100 ml each were collected in sterile sample bottles, one for the Enterolert® test and one for the fecal streptococci. The samples were mixed by pouring from one bottle to the next and back again to insure as much as possible that the two bottles were representative of the sample filtrate. A blank was also filtered through each column before each sample to prove that the column and packing was sterile, and did not contribute to any contamination of the samples.

The following table (Table 2.1) is a summary of the Enterolert® test results:

Sample Location/ Laboratory ID	**Sample Description**	**Location**	**Enterococcus of July 11, 2000 (col./100ml)**	**Enterococcus of June 21, 2000 (col./100ml)**
Blank$_1$	----	Basin HCSBD01	< *1*	----
HCSBS03-00/ M000711-001	Campsite 2089	Basin HCSBD01	29.8	6.2
Blank$_2$	----	Basin HCSBD01	< *1*	----
HCSBS03-01/ M000711-002	Campsite 2068	Basin HCSBD01	270.0	> 2419.2
Blank$_3$	----	Basin HCSBD01	< *1*	----
HCSBS03-01/ M000711-003	Campsite 2075	Basin HCSBD01	93.4	> 2419.2
Blank$_4$	----	Basin HCSBD01	< *1*	----
HCSBS03-03/ M000711-004	Animal Relief Area	Basin HCSBD01	> 2419.2	----
Blank$_5$	----	Basin HCSBD01	< *1*	----
HCSBS03-00/ M000711-005	Beach House B2	Basin SBD01	91.0	177.9
Blank$_6$	----	Basin HCSBD01	< *1*	----
HCSBS02-00/ M000711-006	Beach House B12	Basin HCSBD01	365.4	461.1
Blank$_7$	----	Basin HCSBD01	< *1*	----
HCSBS02-01/ M000711-007	Ocean Lakes Entrance	Basin HCSBD01	365.4	----
Blank$_8$	----	Basin HCSBD04	< *1*	----
HCSBS04-00/ M000711-008	S.P. adjacent to SBD04	Basin HCSBD04	128.1	----
Blank$_9$	----	Basin HCSBD04	< *1*	----
HCSBS04-01 M000711-009	Upstream of SBD04	Basin HCSBD04	1986.28	----

Figures 2.1 and 2.2 are schematic presentations of the sample point locations used in this work. This work indicates that enterococcus is present in the soil and is a potential source of surf contamination during storm events.

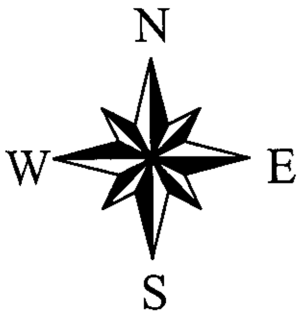


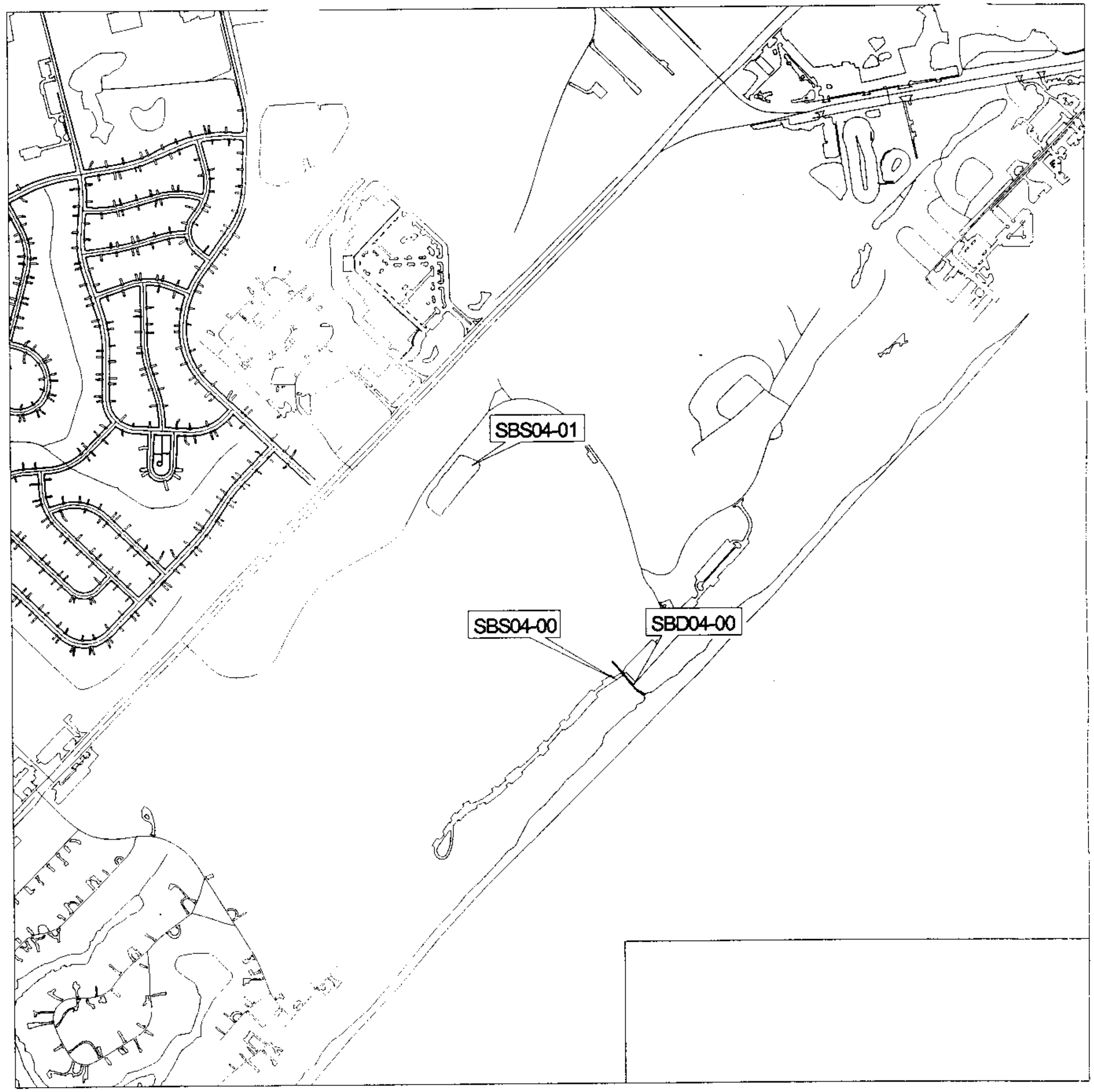


Schematic of Sample Point Locations in Drainage Basins HC SBD01 and HC SBD02

FIGURE 2.1

0.3 0 0.3 0.6 Miles





Schematic of Sample Point Locations in Drainage Basin HC SBDO4

FIGURE 2.2

It is noted that the concentrations of enterococcus in the soil samples collected from areas located on the west side of the dunes and prone to flooding were lower than the concentrations detected in other non-flood prone areas. It is possible that the longer and more severe the flooding the more enterococcus is extracted from flooded areas. The source(s) of the enterococcus in these areas is not known at this time; however, it is suspected that the bacteria originates from animal sources both wild and domestic and perhaps human related sources, such as camper wastewater handling and sewer system overflows and/or malfunctions.

2.1.6 Sediment Considerations in Ponds/Lakes/Lagoons

Understanding that the bacteria of concern originates in the intestine of warm blooded animals and understanding that ducks, geese and other birds are included in this category, one could conclude that the many ponds located in the area should be a source of contamination due to the presence of these animals on the ponds. Additionally, previously discussed data seemed to indicate that high concentrations of enterococcus were the result of elevated suspended solids in the outlet from these ponds during rainfall events and high winds. This raised the question concerning the potential retention of fecal material in pond sediments.

A study was undertaken to evaluate, in a general way, the accumulation of sediment in the ponds, lakes and lagoons within the study area. This evaluation was conducted by measuring sediment depth along a grid system for each of two lakes located within basin HCSBD01. The lake near the pet relief area (near North Sand Dune Drive) and Sand Dollar Lake were evaluated. The sludge depth was measured at each grid location in each lake by retrieving a core sample, from surface to bottom, through the use of a Sludge Judge device. The depth of sediment was recorded for each core sample taken.

The results of this work are presented in the spreadsheet titled Horry County Lagoon Sediment Accumulation found in Table 2.2. A review of the data indicates that the average depth of sediment in the lake near the pet relief area was 0.46 foot and the average depth of sediment in Sand Dollar Lake was 0.30 foot.

A further evaluation was undertaken to consider the impact of sediments on the concentration of enterococcus. During this work, core samples, from the water surface through the sediment to the bottom, were collected from a number of locations. Each sample was separated into a liquid fraction and a sediment fraction. Sub-samples were taken from each fraction and analyzed for enterococcus. The results of this work demonstrated that the concentration of enterococcus in the sediments was consistently higher than that found in the liquid fraction. Often, the concentration of enterococcus in the liquid fraction was less than 100 col./100 mls and the concentration in the sediment was greater than 2,000 col./100 mls. The enterococcus test results of this work are presented on the spreadsheet entitled Horry County Lake, Pond, Lagoon Enterococci Data found in Table 2.3.

The test results identifying the percent human and percent animal bacteria are presented in Table 2.4. It has generally been believed that coliform type bacteria only originate in the intestine of a warm-blooded animal and that the bacteria will not reproduce outside the intestine. However, during this study, some data suggests that the enterococcus were perhaps reproducing at some of the sampling point locations. Dr. Hagedorn of Virginia Polytechnic Institute and State University in Blacksburg, Virginia (VPI) was consulted concerning this possibility, and he informed that recent data indicates that coliform type organisms may actually reproduce outside the host organism.

Horry County
Lagoon Sediment Accumulation

Table 2.2

Lake Near Pet Relief Area Approximate Dimensions 120' X 120'			Sand Dollar Lake Approximate Dimensions 300' X 120'		
Measurement Location	Depth		Measurement Location	Depth	
	Inches	Feet		Inches	Feet
A	1	0.08	A	4	0.33
B	4	0.33	B	3	0.25
C	3	0.25	C	0	0.00
D	6	0.50	D	0	0.00
E	1	0.08	E	2	0.17
F	1.5	0.13	F	8	0.67
G	8	0.67	G	0	0.00
H	7	0.58	H	1	0.08
I	8	0.67	I	0	0.00
J	0	0.00	J	4	0.33
K	1	0.08	K	12	1.00
L	7	0.58	L	3	0.25
M	15	1.25	M	1	0.08
N	14	1.17	N	8	0.67
O	14	1.17	O	8	0.67
P	2	0.17	P	7	0.58
Q	1	0.08	Q	1	0.08
R	4	0.33	R	2	0.17
S	10	0.83	S	3	0.25
T	4	0.33	T	5	0.42
			U	4	0.33
Average	5.6	0.46	V	2	0.17
			W	3	0.25
			X	0	0.00
			Average	3.4	0.3

Horry County

Table 2.3

Lake, Pond, Lagoon Enterococci Data

Date	Location	Enterococcus Col./100 ml. Liquid Fraction	Enterococcus Col./100 ml. Sediment Fraction
20-Jul-00	Surface Briarcliff Southern Lake	276	NA
7-Aug-00	Sediment Drain Side Sand Dollar Lake in Basin HCSBD01	NA	2019
7-Aug-00	Surface Drain Side Sand Dollar Lake in Basin HCSBD01	20	NA
7-Aug-00	Sediment Pet Relief Aera Pond in Basin HCSBD01	NA	311
7-Aug-00	Surface Pet Relief Aera Pond in Basin HCSBD01	10	NA
7-Aug-00	Sediment Sand Dollar Lake in Basin HCSBD01	NA	269
7-Aug-00	Surface Sand Dollar Lake in Basin HCSBD01	20	NA
9-Aug-00	Surface Kingston Northern Lake	5	NA
9-Aug-00	Surface Kingston Southern Lake	5	NA
9-Aug-00	Sediment Kingston Northern Lake	NA	2019
9-Aug-00	Sediment Kingston Southern Lake	NA	2019
9-Aug-00	Surface Briarcliff Southern Lake	94	NA
9-Aug-00	Surface Briarcliff Middle Lake	11	NA
9-Aug-00	Sediment Briarcliff Southern Lake	NA	2019
9-Aug-00	Sediment Briarcliff Middle Lake	NA	2019
16-Aug-00	Sediment Sand Dollar Lake in Basin HCSBD01	NA	520
16-Aug-00	Sediment Briarcliff Southern Lake	NA	710
16-Aug-00	Sediment Briarcliff Middle Lake	NA	900
17-Aug-00	Surface Sand Dollar Lake in Basin HCSBD01	51	NA
17-Aug-00	Surface Briarcliff Southern Lake	52	NA
17-Aug-00	Surface Briarcliff Middle Lake	10	NA

NA= Non-Applicable

He further stated that the data suggests that for this to be possible the conditions in the ambient environment would have to be conducive for reproduction. The conditions believed to be necessary include warm temperatures, a somewhat neutral pH and a food source. It was noted that the conditions in the lagoons and other areas of standing water within the study area seem to meet these criteria.

In addition to the above, a laboratory exercise was performed wherein core samples, both liquid and sediment, were mixed and a sub-sample was taken of the mixed solution for analysis. The remaining sample was allowed to settle for 24 hours and a second sub-sample was taken for analysis. This exercise was performed to simulate the conditions likely present in lagoons during storm events. The exercise was to further project the affect of the storm event and related flow turbulence on enterococcus results. The results of this work were as follows:

Sample Location	Initial Enterococcus (Mixed Sample)	Final Enterococcus (After 24 Hrs. Settling)
Drain Side Sand Dollar Lake	>2000 col./100 mls	663 col./100 mls
Upper End Sand Dollar Lake	>2000 col./100 mls	156 col./100 mls
Upper End Pet Relief Lake	>2000 col./100 mls	152 col./100 mls

2.1.7 Bacteria Source Tracking - Fecal Scoring Results

During the scope refinement phase of this project, it was hypothesized that coliform bacteria as measured by the enterococcus test method would be detected throughout the area. This hypothesis was based on the understanding that the bacteria originate in the intestines of warm-blooded animals and that birds, ducks, dogs, and cats, as well as humans, are included in the list of warm-blooded animals expected to contribute. With so many potential sources of bacteria in the area, it was believed that if we could determine if the bacteria detected originated from human beings or from other animals we could direct our investigations toward sources that would most likely be contributing. It was felt that if the origin of the bacteria could be identified as being predominately human or predominately other animals, it would be more likely that solutions could be developed. A number of methods are under evaluation to differentiate between coliform originating from human and animal sources. These methods include the use of antibiotic resistance profiling and randomly amplified polymorphic DNA (RAPD) testing of fecal bacteria. Representatives of EPA identified Dr. Charles Hagedorn as a leader in the field. Dr. Hagedorn is Professor of Crop and Soil Environmental Science at VPI. Dr. Hagedorn has received numerous awards from the U.S. Department of Agriculture and the Environmental Protection Agency for service in developing a permitting system for field testing genetically engineered microorganisms, and he currently holds a governor's appointment to the Virginia Health Department's Appeal Review Board. Enclosed in Appendix I are copies of two technical papers that present information on this type of analytical work.

During this work, a number of sample points were selected for inclusion in an evaluation to determine the source of the bacteria. In this process, samples with known elevated enterococcus concentrations were cultured for fecal streptococcus bacteria by Davis & Floyd, Inc. personnel. The plated streptococcus colonies were packed in cooled ice chests and shipped to Dr. Hagedorn at Virginia Tech for further analysis. The results of this work are presented on Table 2.4.

2.1.8 Bacteria Considerations at Background Locations

Understanding that coliform bacteria originate in the intestines of warm-blooded animals, it was considered necessary to address the potential concentration of enterococci in waters thought to be free of human influences.

Table 2.4

Horry County

Myrtle Beach, South Carolina

Enterococcus Bacteria - % Human & % Animal

Sample Identification	Sample Location	Date	Isolates*	% Human	% Animal
HCSBD01-00	Swash At South End of Basin HCSBD01	7-Jun-00	48	10.4	89.6
HCSBD02-00	Drainage Pipe at North End of HCSBD01	7-Jun-00	48	14.6	85.4
HCSBD03-00	Swash At Basin HCSBD03	7-Jun-00	35	15.8	84.2
HCSBD04-00	Swash Near Basin HCSBD04	7-Jun-00	96	5.4	94.6
HCLAD01-00	Singleton Swash @ HCLAD01	9-Jun-00	16	18.7	81.3
HCLAD02-00	Pipe at The Northern End Of Kingston Plantation at The South End of the Wyndham Hotel Parking Lot	9-Jun-00	8	0.0	100.0
HCLAD03-00	Roof Drain From The Wyndham Hotel	9-Jun-00	96	0.0	100.0
HCLAD06-00	White Point Swash (Briarcliffe Acres Bridge to Beach)	9-Jun-00	28	50.0	50.0
HCSBD01-00	Swash At Basin SBD01	19-Jun-00	48	52.6	47.4
HCSBW03-00	Pipe at Seaside Drive near lot 1038, just south of swash in Basin HCSBW03	19-Jun-00	48	33.3	66.7
HCSBD02-00	Drainage Pipe at Basin HCSBD02	19-Jun-00	48	62.5	37.5
HCSBW11-00	Wash Out by The Pool at Lakewood Campground	19-Jun-00	48	17.4	82.6
HCSBD03-00	Swash At HCSBD03	19-Jun-00	48	63.8	36.2
HCSBD04-00	Swash Near @ BasinHCSBD04	19-Jun-00	48	70.0	30.0
HCLAD01-00	Singleton Swash	19-Jun-00	48	0.0	100.0
HCLAD02-00	Pipe at The Northern End Of Kingston Plantation at The South End of the Wyndham Hotel Parking Lot	19-Jun-00	48	20.8	79.2
HCLAW01-00	Drain Pipe to Beach at The Wyndham Near HCLAD03.00	19-Jun-00	48	4.3	95.7
HCLAW02-00	Drain Pipe North of HCLAD03.00 and South of HCLAD01.00	19-Jun-00	48	60.4	39.6
HCLAD06-00	White Point Swash (Briarcliffe Acres Bridge to Beach)	19-Jun-00	48	57.9	42.1
HCSBS03-03	Soil Beside Lot 3022 in Basin HCSBD01	11-Jul-00	40	35.9	64.1
HCSBS03-02	Soil Beside Lot 2075 in Basin HCSBD01	11-Jul-00	2	12.5	87.5
HCSBS02-00	Soil Near Beach House B2 in Basin HCSBD01	11-Jul-00	30	31	69
HCSBS01-00	Soil Near Beach House B12 in Basin HCSBD01	11-Jul-00	48	4.3	95.7
HCSBD02-00	Drainage Pipe @ BasinHCSBD02	27-Jul-00	48	0	100
HCSBD01-06	Pipe Behind Snack Bar in Basin HCSBD01	27-Jul-00	48	75.8	25.2
HCSBD03-00	Swash @ Basin HCSBD03	27-Jul-00	36	20.8	79.2
BARUCH **	3Rd. Boundary Culvert	27-Jul-00	48	0	100
HCLADUP	Briarcliff Upper Pond	24-Aug-00	48	8.3	91.7
HCLADSE.00	Briarcliff Pond South End	24-Aug-00	48	16.7	83.3
HCSBS01.02	Sand Dollar Lake - Basin SBD01	24-Aug-00	48	0.0	100.0
HCSSB03 **	Upper End of Lake Elizabeth (Surfside Beach)	24-Aug-00	48	29.2	70.8
HCSSB11 **	Swash From Lake Myrtle at North Ocean Blvd.	24-Aug-00	48	62.5	37.5
	Unknown To Lab - Cat	24-Aug-00	48	10.0	90.0
	Unknown To Lab - Human	24-Aug-00	48	86.2	13.8

* = Colonies isolated for evaluation

** = Outside study area

Finding a largely pristine site in the Myrtle Beach area is somewhat difficult; however, after consideration of the alternatives, the site of the Belle Baruch Marine Laboratory located on Hobcaw Barony near Georgetown, South Carolina was chosen. Contact was made with Mr. George K. Chastain, Plantation Manager, for the site to gain access and to obtain a recommendation of a sampling point location. Mr. Chastain was very helpful and assisted Davis & Floyd, Inc. in the selection of two sampling point locations. Two random samples were taken in ditches near the center of the reserve. Both samples were taken during periods that did *not* involve a rain event from sources that were very slow moving to having no flow. The samples were collected and analyzed for enterococci with the following results:

3rd Boundary Road North	>2419 col./100 ml
3rd Boundary Culvert	548 col./100 ml

In addition to the above analysis for enterococcus bacteria, fecal streptococcus analyses were set up to provide colonies for further analysis by Dr. Hagedorn at Virginia Tech. The samples were sent as blind samples to Dr. Hagedorn, in that he did not know the origin of the samples, nor the reason that the samples were collected. The analysis indicated that the samples from the plantation were of 100% animal origin. This provides a level of confidence in the other testing, in that the method was able to correctly identify that the bacteria in the sample uncontaminated by humans was 100% non-human. More background samples from pristine undeveloped areas may be beneficial.

2.1.9 Groundwater Considerations

At the beginning of the study period, Davis & Floyd, Inc. was informed that a number of the bathhouses and/or restrooms at Myrtle Beach State Park were served by septic tanks. In addition and during the early part of this study, enterococcus contamination was detected at the swash located at the State Park. An activity was, therefore, planned to evaluate the potential of the septic tanks as a source of the contamination. On July 12, 2000, a hand auger was used to excavate a hole from the surface to the depth of groundwater saturation. This hole was excavated in the undergrowth located between the bathhouse and the swash for basin HCSBD04 sampled as a part of this study. The excavation was near the picnic area. The excavation was terminated at a depth of approximately five feet. It was noted that the soil at this location was very sandy to a depth of over four feet and then a dense layer of organic like material was found. It seemed that the groundwater was flowing vertically until the dense layer was encountered, and then it appeared to flow horizontally along the surface of the organic layer. Separate samples of groundwater and saturated soil were collected. An enterococcus analysis was performed on each sample. This was done to evaluate, in a preliminary way, the potential impact of enterococcus bacteria on groundwater in the area. At the time that the samples were taken, it was believed that the bathhouse was on a septic tank. It has since been determined that the bathhouse is on a sewer system. The results of this work demonstrated that the groundwater sample contained 2.0 colonies per 100 milliliters and the saturated soil contained 520 colonies per 100 milliliters.

After completion of the activity described above, Davis & Floyd, Inc. learned through discussions with the South Carolina Parks, Recreation and Tourism (SCPRT) in Columbia, SC, that the systems at the State Park that were on septic tanks had been changed over to the sewer system some years ago. After consideration of this new information, and the information generated through the field and laboratory activity described above, it may be concluded that enterococcus can be detected in the groundwater located in the initial saturated zone in this area. It is expected that the groundwater in this zone will leach, in time, into adjacent swashes and on to the surf.

However, the data generated during this activity indicates the impact of the groundwater is likely minimal, at least in the area that is now served by a sewer system.

In addition to the above, on August 2, 2000, groundwater samples were collected at two locations. The locations were as follows:

*Adjacent to the sewer pumping station located near sampling point HCSBD02.

*Near sampling point HCSBD04.

The results of this work demonstrated that the groundwater at both locations contained concentrations of enterococcus at >2,419 col./100 ml. The results of this work indicate that problems associated with sewer and/or pump station leaks and/or overflows could be a source of contamination in these areas and that further investigations are needed to better define conditions.

2.1.10 Surf Monitoring

During the performance of this study, surf-monitoring activities were undertaken for the South Carolina Department of Health and Environmental Control (SCDHEC). Nine of the SCDHEC surf monitoring locations were in close proximity to the dry weather discharges and/or swashes utilized in the Horry County project. The SCDHEC sampling points within the Horry County study area were identified as follows:

WAC – 10	Briarcliff Cabana
WAC – 11	2 Miles North of Wyndham Hotel
WAC – 12	Lands End
WAC – 13	Wyndham Hotel
WAC – 15	Singleton Swash
WAC – 27	Myrtle Beach State Park

WAC – 28	Pirateland – Lakewood Campground
WAC – 29	Ocean Lakes Campground
WAC – 30	16th Ave. North

The location of the above, with respect to the Horry County dry weather monitoring points, is presented in Appendix K. In addition, the surf monitoring data generated at the above locations during the months of June – September 2000 is presented as Table 2.5. The data presented in Table 2.5 demonstrates that the surf in areas adjacent to the discharges monitored as a part of this project are often contaminated with excessive concentrations of enterococcus. The data further confirms that the highest concentrations were detected during and/or after rainfall events. The indication from these facts is that the elevated bacteria concentrations in the discharges and the elevated volume due to the rain contribute to contamination in the surf.

2.1.11 Consideration of the Effects of Turbulence on Lake TSS Concentrations

An experiment was conducted to evaluate the effects of turbulence within the lake system upon the total suspended solids (TSS) concentration in the water column. For this evaluation, core samples were collected from three lakes in the study area. The lakes sampled as a part of this work were the southernmost lagoon at Briarcliff, the middle lagoon at Briarcliff and Sand Dollar Lake in basin HCSBD01. The core samples were collected through the use of a Sludge Judge . Each sample was placed in sample bottles and transported to the Davis & Floyd, Inc. Mobile Laboratory located at the Myrtle Beach, South Carolina Air Force Base for evaluation. In the mobile laboratory, each sample was mixed and a sample fraction was removed for analysis. Each sample fraction was analyzed for total suspended solids (TSS). The remaining portion of each mixed sample was allowed to stand and solids settle for a twenty-four hour period. After the settling period, a sample fraction was retrieved from the supernatant (water) layer of each sample. The sample from the water layer of each sample was analyzed for total suspended solids (TSS).

Horry County

Table 2.5

Myrtle Beach Surf Monitoring In Horry County Study Area

Date	WAC-10 Briarcliff Cabana Enterococcus col./100ml.	WAC-11 2 Miles North of Wyndham Enterococcus col./100ml.	WAC-12 Lands End Enterococcus col./100ml.	WAC-13 Wyndahm Hotel Enterococcus col./100ml.	WAC-15 Singleton Swash Enterococcus col./100ml.	WAC-27 Myrtle Beach State Park Enterococcus col./100ml.	WAC-28 Pirateland - Lakewood Campground Enterococcus col./100ml.	WAC-29 Ocen Lakes Campground Enterococcus col./100ml.	WAC-30 16th. Ave. North Enterococcus col./100ml.
6-Jun-00	20	10	10	10	10	74	41	171	301
7-Jun-00	-	-	-	-	-	-	-	10	20
8-Jun-00	-	-	-	-	-	-	-	41	31
20-Jun-00	10	10	10	20	3879	10	345	10	10
21-Jun-00	-	-	-	-	-	-	10	-	-
23-Jun-00	10	10	20	10	10	10	10	20	278
23-Jun-00	-	-	-	-	-	-	-	-	10
30-Jun-00	10	31	51	10	291	10	10	10	41
1-Jul-00	-	-	-	-	20	-	-	-	-
6-Jul-00	10	10	41	10	52	31	20	10	10
13-Jul-00	3076	5794	6867	9333	697	5794	865	24192	9208
14-Jul-00	738	121	10	41	96	581	6488	1607	609
15-Jul-00	20	10	-	-	-	98	243	63	63
16-Jul-00	-	-	-	-	-	-	20	-	-
20-Jul-00	10	10	10	20	10	84	85	74	10
23-Jul-00	31	10	20	20	10	20	20	30	31
26-Jul-00	146	20	52	41	30	20	959	74	30
27-Jul-00	52	31	10	63	94	10	52	52	10
3-Aug-00	20	10	10	10	10	10	84	10	10
5-Aug-00	30	1	30	10	85	1036	52	336	20
10-Aug-00	10	10	30	20	10	31	933	10	312
11-Aug-00	-	-	-	-	-	-	10	20	-
12-Aug-00	10	10	10	20	10	10	74	52	96
16-Aug-00	10	20	10	10	20	10	246	30	10
11-Sep-00	10	10	10	20	10	-	-	-	-
12-Sep-00	-	-	-	-	-	10	10	187	10
13-Sep-00	-	-	-	-	-	-	-	161	-
27-Sep-00	110	121	41	20	10	20	10	52	107

The results of this work are presented as follows:

Sample Location	Initial TSS Concentration in mg/l	TSS Concentration After 24 Hours in mg/l
Briarcliff Southern Lagoon	2140	53.4
Briarcliff Middle Lagoon	1240	46.2
Sand Dollar Lake	2580	103.0

The complete results of this work are presented in laboratory report form in Appendix H. This data along with the enterococcus in sediment data presented earlier indicate that conditions that result in turbulence in the lagoon/drainage systems also could result in the discharge of elevated total suspended solids that contain enterococcus to the surf. Turbulence within the system may be the result of increased flow due to rainfall, surface wind and other natural weather related conditions.

3.0 SOURCES OF CONTAMINATION

In an effort to identify the sources or potential sources of bacteria contamination, the Davis & Floyd, Inc. team performed an extensive field investigation of the study area using maps, aerial photographs, new and existing sampling data, existing research, as well as conducted specific laboratory experiments and interviews. This section outlines many of the potential sources of contamination.

3.1 Septic Tank/Drain Field

Leachate from septic tanks and associated drain fields are a potential source of microbiological contamination of recreational waters, particularly from septic systems that are poorly maintained. Septic tank systems can also contribute to contamination of recreational waters in areas where the septic tanks and associated drain fields are located in shallow water table situations and/or experience flood conditions.

The vast majority of the study area is served by sanitary sewer systems, however there are some areas that are served by septic systems. A single home septic system alone may pose a small risk of environmental contamination. However, this study did not encounter any isolated situations where a single residence or only a few residences were served by septic systems. Large areas or neighborhoods where septic systems predominate and where the potential for flooding is significant present a greater potential source of contamination. The residences throughout the Briarcliff Acres area are served by septic systems. Significant flooding was observed in this area on several occasions over the course of the study. During the study, it was common to observe homeowners in the Briarcliff Acres area pumping storm water from their homes, garages and yards into the street so that it would flow unrestricted to surface tributaries of the surf. The percentage of isolates (bacteria) from two selected samples collected from White Point Swash in the Briarcliff Acres area resulted in 50% and 57% human contribution, respectively. This was significantly higher than most of the other samples taken from the study area where the percentage of human vs. animal waste was analyzed.

3.2 Non-Storm Water Discharges

Sewage retaining systems, such as portable toilets and dump stations, that are specific for recreational areas may be a potential source of microbiological contamination of waters. The potential contamination may occur if the systems are poorly maintained or if their contents are otherwise released through accidental, improper operations, or deliberate action. Possible sources of contamination include releases from recreational vehicle holding tanks, dump stations, pumping stations, sewer line leaks, RV hook-ups and portable toilets.

The individuals who are using those waters for recreation may be another source of contamination of marine recreational waters. Constituents of residual fecal matter may be washed off the body on contact with water, with most of it washed off within a relatively short time after submersion. Hence, swimmers, bathers, waders, surfers, the fishing population, and others who may come into full- or most-body contact may all contribute to contamination to which they are exposed. Infants in diapers and young children, as well as other individuals, may also contribute significantly to contamination by accidental fecal releases. Others may cause contamination by intentional fecal releases, because of a lack of proper sanitary facilities at or near the recreational area, or because such facilities though present, are not used.

Public and private outdoor showers may also be a source of contamination. Showers were found along the beach at countless locations. Condominiums, hotels, campgrounds and various resorts commonly provide showers for beach goers to rinse off when coming off of the beach. Many of the private homes have outdoor showers as well. Bathers could contribute to the contamination at these shower locations, which typically are not tied to a sewer system and discharge directly on to the ground.

3.3 Sewer Overflow

System failures in human sewage treatment facilities, including pump stations, force mains, manholes, and gravity sewer lines, may be a large contributor to the contamination. Sewage overflows can occur for a number of reasons, including localized blockages, failure of pumping systems, undersized lines, storm water impacts, etc. The result is a surcharge of the system, which in turn causes overflows through holes in manhole covers, through constructed outlets such as cleanouts, through drains, or through pump station overflow pipes.

Localized blockages can occur due to obstructions such as bricks, sticks, plastic bags, roots, debris, rocks, sand, and solidified grease build-up in the line. They can also occur due to broken or crushed pipes and joint failure. Debris can enter the sewer from construction activities, vandalism, and even from sewer maintenance work. Unique to areas such as Horry County, with several campgrounds with sewer connections for recreational vehicles, it is not uncommon for the owner of a recreational vehicle to accidentally drop a flexible sewer connection hose into the wastewater sewer hook up.

Flooding in Campground

Overflows commonly occur during wet weather conditions, when infiltration and/or inflow overload the sewer system. Infiltration is typically the result of extraneous water entering the sewer system through joint leaks in pipes and/or manholes, and occur when the water table elevation rises above the pipe inverts as the result of heavy rains which impact the water table elevation. Inflow occurs from many sources and is the result of surface runoff entering the sewer.

Flooding Behind Dunes

Davis & Floyd, Inc. personnel observed significant storm water back up on the backside of the dunes in the study area. When the storm water is allowed to backup behind the dunes, it is possible that flow enters the sanitary sewer systems through manholes and even legal sewer hook ups that turn out to be below the surface elevation of the backed up storm water. The photographs herein are examples of storm water back up behind the dunes. A major source of inflow is typically illegal storm drain connections to the sewer, such as roof storm drains, crawl space and basement pumping systems, roadway and parking lot storm drains, etc. Additionally, inflow can result from surface runoff entering the system through holes. A common inflow problem is a manhole cover with holes located in an area that floods, allowing the surface runoff to enter the system through the manhole cover holes. This can also occur where the sewer pipe has broken in an area that floods, or in an area where a pump station is subject to flooding. These situations were observed in several locations throughout the study area, i.e. sewage systems in many of the areas close to the beach are not able to process the volume of water that enters them during excessive rain events and flooding. Grand Strand Water and Sewer Authority (GSW&SA) indicated that several sewer overflows were known to have occurred during the study period. The pump station near the intersection of SC544 and US 17 overflowed in July for over 30 minutes, because the force main was clogged. While working in Pirateland Campground in August, a contractor cut a force main that spilled wastewater into the swash. It is not uncommon for several of these overflows to occur each year. GSW&SA also indicated that their systems are not significantly impacted by rain events less that two inches. More problems are seen when rain events exceed four inches. They indicated areas where storm drainage improvement might help eliminate sewer overflows include Forest Brook, Deerfield Plaza, and Garden City between the inlet and US 17 Bypass. They also noted that the ponds in Ocean Lakes have been known to overflow the banks.

3.4 Animal Waste

Animal wastes also contribute to contamination, though it is generally assumed that such contamination represents a less substantial human risk than contamination resulting from human sewage. The currently used test methods do not distinguish between bacteriological contamination from animals and humans. Both wild and domestic animals serve as vectors for microbiological parasites. To the extent that animals may be allowed on beaches or other inland recreational properties, their wastes add to the microbiological burden of recreational waters. Numerous dogs were encountered on a daily basis during the study. In at least one case, owners were provided a specific location for their dogs to relieve themselves. The photograph above is of a pet relief area in one of the campgrounds. In addition, it is not uncommon to see people riding horseback on the beach within the study area. Wild animals such as deer and raccoon are commonly found in the study area. Large populations of ducks, geese, Canadian geese, seagulls, and other waterfowl, as well as numerous birds, were

Pet Relief Station Near Outfall HS SBD02-00

Ducks at Pond - Typical Throughout Study Area

encountered throughout the study area. A nest of swans was also found during the study. All of these contribute significantly to the contamination problem.

4.0 STRATEGIES FOR DEALING WITH CONTAMINATION

4.1 Eliminate Septic Tank/Drain Fields

Considerations should be given to elimination of septic tank and drain field systems wherever possible. A study should be completed to identify all septic systems within this study area. Each of these systems should be evaluated to determine the feasibility to connect these systems to a sanitary sewer system. Special considerations should be given to the Briarcliff Acres area, which is currently known to use individual septic systems. In addition, according to the data generated during this project, the waters adjacent to this area exhibited a large percentage of bacteria isolates that originated from human sources. This area was also observed to be prone to significant flooding and residents often pumped surface water from their yards and dwellings directly to the street.

4.2 Improve Sewer System

Considerations should be given to improving the current sewer systems, starting with the systems that have a history of, or are most susceptible to, blockages and overflows. Infiltration/Inflow (I/I) studies should be conducted in these areas to determine the sources of extraneous water and the corrective action necessary to eliminate this water. Consideration should be given to TV inspection of the sewer systems in these areas as a part of the I/I studies. These studies should be able to locate illegal storm water connections to the system, as well as areas in need of repair or replacement.

4.3 Improve Storm Water Drainage

It was determined that flooding occurs in numerous locations throughout the study area, resulting in cross-contamination of the storm water with sewage. Consideration should be given to improving storm water drainage in areas that could impact sanitary sewer systems. For example, storm water tends to pond behind the dunes in many of the campground areas causing sewer line inflow at sewer connections as well as sewage overflow. This appears to be caused by the fact that many of the storm water drainage pipes through the dunes are no longer functional.

4.4 Eliminate Non-Storm Water Discharges

A number of non-storm water discharges were identified during the study. These discharges are most likely contributing to the overall contamination problem. Some of the possible sources of non-storm water contamination include releases directly on the ground from recreational vehicle holding tanks, recreational vehicle wastewater connections, dump stations, pumping stations, sewer line leaks, portable toilets, illicit wastewater discharges, outdoor showers, swimmers, children's diapers, as well as wild and domestic animals. It is recommended to begin the process of eliminating and/or managing these and other potential pollution sources as soon as possible.

4.5 Promote Tight Seals at Campgrounds

Standards should be established which would promote tight seals at all connections from the recreational vehicles to the wastewater sewer hook ups. Caps for all unoccupied RV sites should remain closed tightly at all times. Use proper seals such as "donuts" where the flexible hose connects to the wastewater hook up. Proper clamps should be used to attach the flexible hose to the RV. The combination of these procedures will serve to reduce the amount of fecal material inadvertently spilled on the ground or paved areas and subsequently discharged to the surf.

4.6 Promote Proper Operation

Establish proper operating procedures for using, connecting, and disconnecting RV holding tanks to the sewer system. These proper procedures would include how to make tight connections and how to hook, unhook, and properly drain the hose. Other procedures would include avoiding knots in the hose, loosing the hose in the sewer, and allowing the hose to rest below the hook up port. This information should be published and given to a person in each recreational vehicle entering any campground.

4.7 Dredge Sediment from Pond Bottoms

Results of several of the tests performed during this study indicate that bacteria are being stored and/or reproduced in the sediment at the bottom of most of the storm water retention ponds and recreational lagoons. Coliform (enterococcus) test results on samples from pond bottoms were found to be consistently higher than the results of samples collected at the top of ponds. A conclusion that may be drawn from that information is that bacteria are being stored and/or reproduced in the sediment on the bottom of the ponds. This is further supported by comparing the results at outfalls on windy days to the results on days with little or no wind. The elevated results on windy days seem to indicate that the wind mixes sediment on the pond bottom, which discharges water with higher bacteria counts and total suspended solids. Considerations should be given to dredging the bacteria laden sediment from the pond bottoms, although this will be a short-term temporary solution that will have to be repeated on a regular frequency.

4.8 Treat Pond to Eliminate Bacteria

Some of the documents researched during this study indicate that enterococcus bacteria thrive best at specific ranges of temperature and pH. As a part of this study, Davis & Floyd, Inc. performed a bench-scale test to evaluate the addition of lime to eliminate enterococcus. On September 6, 2000, a laboratory exercise was performed to evaluate the possibility that a pH change may be utilized to kill enterococcus bacteria. The addition of lime to elevate pH values was used in this evaluation. This evaluation was performed as follows:

- A sample of sediment was collected from Sand Dollar Lake
- An enterococcus test was performed on a portion of the sample.

- The pH of a second portion of the sample was adjusted to 8.5 units through the addition of lime.
- An enterococcus test was immediately performed on the portion of the sample with the pH adjusted to 8.5 units.
- The pH of a second portion of the sample was adjusted to 10.5 units through the addition of lime.
- An enterococcus test was immediately performed on the portion of the sample with the pH adjusted to 10.5 units.

The results of these tests were as follows:

• Sand Dollar Lake sample	1,413.50 Col./100mls.
• Sand Dollar Lake sample adjusted to pH 8.5	866.4 Col./100mls.
• Sand Dollar Lake sample adjusted to pH 10.5	816.4 Col./100mls.

The above results, reduction of approximately 42%, were achieved without the advantage of detention time at the elevated pH. This evaluation was to simulate the simple pH adjustment of surface water and/or storm water without providing containment for detention. The addition of detention time may be more effective in the eliminating of the enterococcus bacteria. We recommend an actual full-scale test on one of the ponds to evaluate this method as a source of controlling the release of enterococcus bacteria. We feel that this may have a significant impact on readings taken in the surf during and following rainfall events.

4.9 Pipe Outfalls from Beach to Ocean Bottom

Consider capturing flow from outfalls and swashes and piping these flows to a discharge point out in the ocean. This discharge point would need to be deep enough in the ocean and far enough out that the dilution effect and salinity impact on the bacteria would result in reduced bacteria counts in the recreational areas adjacent to the shore.

4.10 Pipe Outfalls from Beach to Intracoastal Waterway

Consider capturing flow from outfalls and swashes and piping these flows directly to a discharge point in the Intracoastal Waterway or to the waterway through a constructed wetland treatment system. It would be necessary to conduct a study to consider the potential affects of this alternative on the water quality in the waterway and adjacent ocean outlets. The dilution effect and salinity impact on bacteria in this large body of water may prove to be beneficial.

5.0 CONCLUSIONS AND RECOMMENDATIONS

5. 1 Conduct Enterococcus Bacteria vs. Time and Rainfall Intensity Study

As a result of a review of the data contained in this report, it is recommend that a study be conducted to consider enterococcus bacteria concentration vs. time and rainfall intensity. This should be done to address how long rain events impact bacteria in the surf. High counts of enterococcus bacteria were encountered during and after every rain event. Currently, when high counts occur, up to 24 hours or more has passed before a warning is issued. When high counts occur, an additional round of surf monitoring is automatically performed. The results of the additional round are available 24 hours later. Usually, the additional results are in a normal range and the warning is lifted. It is recommended that warnings be issued during and after each rain event. The recommended study would compile data from as many rain events as practicable, particularly during peak season. Surf monitoring would be performed during these rain events at pre-determined time intervals. Samples would be collected and analyzed over a period of time until surf bacteria counts return to normal. The surf monitoring results and rainfall intensity would be plotted over time in an attempt to generate a chart that could be used to predict how long to wait before lifting the warning after a rain event. Based on the data available, and using an appropriate safety factor, officials should be able to more accurately issue and lift warnings during the actual period that the bacteria counts are elevated. Such a procedure would be utilized until sources of contamination can be eliminated or significantly reduced.

5.2 Eliminate Swimming in Swashes

This report recommends the need to continue warnings against swimming in swashes until further study can define periods when the bacteria levels would not be elevated. The enterococcus bacteria concentrations measured in swashes were almost always elevated, even before rain events. As was stated earlier in this report, adults and children alike were observed playing in swashes at all locations.

5.3 Provide Sewer to Briarcliff Acres

The Briarcliff Acres community is the only large area identified in the study that is served by septic tank and drain field systems. Flooding was observed in portions of this community during several rain events. Because of the potential for septic tank and drain field dispersion of leachate during flooding, it is recommended that Briarcliff Acres be evaluated to determine the feasibility of connecting the homes in this community to a sanitary sewer system.

5.4 Identification and Investigation of Septic Tank Areas

It is recommended that an investigation be undertaken to identify areas, other than Briarcliff Acres, that are served by septic tanks. This investigation should start with a review of the records available at the South Carolina Department of Health and Environmental Control as well as other local agencies and conclude with a field investigation.

5.5 Study Design Possibilities to Pipe Outfalls from Beach to Ocean Bottom

As noted previously, coliform counts along the shore could be decreased by piping the outfalls into the ocean, resulting in dilution, as well as toxicity to the coliform as a result of high salinity values. It is recommended that a study be instituted to evaluate the feasibility of piping all swashes and the outfall discharges to the ocean bottom and/or the Intracoastal Waterway.

5.6 Develop and Implement Educational Program

The establishment of educational programs to inform residents and visitors of potential measures that can be taken to help prevent storm water pollution is also recommended. The program for residents would help inform the local residents of potential point sources. This information could be published in the local newspaper and/or inserted in flyers with one of the many utility bills sent out such as telephone, cable, power, water/sewer, etc. A program specifically for campgrounds would provide campers with proper training for how to connect and disconnect to the wastewater hook-ups. This information would be provided to the user when entering the campground. Another program could be distributed to hotel and condominium guests upon arrival. This program would inform guests of potential pollution sources that they may be able to manage such as animals, children's diapers, and outdoor showers.

5.7 Ordinances and Regulations

It is recommended that consideration be given to the formulation of ordinances to prevent or require certain activities such as cleaning up after pets. The use of ordinances could be publicized and used as a tool to reduce bacteria contamination in the surf.

5.8 Evaluate and Improve Drainage to Decrease Flooding Where Practicable

It is recommended that a feasibility study be made to evaluate existing drainage and determine where improvements can be made to decrease flooding. The initial focus of this study should be around sanitary sewer systems, which have the greatest potential for overflowing during flooding. One of items of greatest concern would be gravity sewer lines and pump stations serving complexes and that are close to the beach. Additional consideration should be given to adding storm water outfall pipes through the dunes or campgrounds to repair outfall pipes that exist, but are not operational. These additions and repairs may help reduce flooding in some of these areas.

5.9 More Extensive Study in Individual Outfalls

Horry County requested that this study attempt to identify outfalls that contribute most to pollution. Once identified, that outfall or drainage area would be studied in more detail. All of the outfalls were found to receive equally high results during rain events. Therefore, during discussions with Horry County, it was agreed that the study would focus on drainage areas HCSBD01 and HCLAD06 because they have many of representative issues found throughout the study area. As is the case with almost all environmental problems, whenever practicable, the elimination or management of the actual pollution source is preferred over other solutions. It is recommended that a more extensive study be made in several individual drainage basins to identify the actual pollution source(s). Steps could then be taken to manage or eliminate the actual pollution source. It is recommended that the drainage basin (HCLAD02) which includes a lagoon system within and adjacent to the Kingston Plantation be incorporated in the additional studies. After reviewing the data from this study, it would also be recommended to further study drainage basin HCSBD03.

5.10 Urban Run-off

A review of the data presented in this report, as demonstrated by the fact that most all dry weather discharges and all wet weather discharges to the surf are contaminated with bacteria, indicates a need to investigate further urban run-off. It is understood that as development increases so does the area under pavement. The pavement prevents natural rainfall percolation into the water table and increases the run-off volume to the surf. In non-paved areas, fecal material from wildlife will be naturally degraded through normal biological activity, and the non-degraded portion remaining will seep into the soil over a wide area and be further degraded. In paved areas, droppings from wildlife will degrade to a degree in place and that remaining portion will be flushed from the area and discharged to the surf during rainfall events. It is recommended that urban run-off and the treatment of the run-off be considered as a part of development planning. During this phase of planning, it may be possible to provide natural or constructed wetland areas to assist in the assimilation of waste materials.

5.11 Establish Program with Grand Strand Water and Sewer Authority (GSW&SA) to Eliminate Sewer Overflow

It is recommended that Horry County establish a formal working relationship with Grand Strand Water and Sewer Authority (GSW&SA) in an effort to eliminate wastewater impacts on storm water. Working together with GSW&SA could provide opportunities to eliminate sewer overflows caused by flooding and poor drainage problems. Teaming together to perform Infiltration/Inflow (I/I) studies may prove to be productive for both parties. Reducing I/I will reduce hydraulic flows to the treatment plants during and following rain events, thereby improving treatment efficiency. Additionally, reducing I/I may eliminate sewer overflows that result in cross-contamination of storm water. It may be beneficial to perform I/I studies in several of the private campgrounds within the study area.

5.12 Study Impact of Dredging or Treating Ponds

Several of the tests performed during this study indicate that the bacteria from a variety of sources may be stored and may possibly be reproducing in the sediment at the bottom of ponds. Test results on samples from pond bottoms were consistently found to be higher than the results of samples collected at the top of ponds. Elevated bacteria counts on windy days at outfalls that are fed by ponds point to the theory that bacteria are being stored in the sediment on the bottom of pond and re-suspended by the wind/wave action. The elevated results on windy days seem to indicate that the wind mixes sediment on the pond bottom, which seems to discharge flow with higher bacteria counts. Considerations should be made to periodically dredge the bacteria laden sediment from the pond bottoms. As part of this, consideration should be made involving any potential adverse impacts dredging may cause.

Previous studies indicate that enterococcus bacteria thrive best at specific ranges of temperature and pH. As a result, this study considered what might happen to enterococcus bacteria when the pH was adjusted. As part of this study, a bench top experiment was performed by adding lime to a sample known to have a high concentration of enterococcus bacteria. The experiment indicated a significant reduction in bacteria after the treatment. The results of the experiment were based on a lime treated pH contact time that was immediate; therefore, additional laboratory tests should be performed to evaluate the effects of detention time on this potential treatment process. After completion of the laboratory tests, and if the further testing confirms and better defines the results expected, it is recommended that consideration be given to actually treating a number of the ponds by adjusting the pH. These tests should be under controlled conditions to insure that fish and other wildlife are not affected by the elevated pH values.

5.13 Consider Raising Limits for Beach Warnings

During discussions with officials of the South Carolina Department of Health and Environmental Control (SCDHEC), it was learned that bacteria originating from warm-blooded animals other than man may be of less concern than the bacteria originating from human sources. Generally, humans are less susceptible to diseases carried by fecal bacteria originating from animals than ones carried by fecal bacteria originating from humans. At this time, no totally proven and accepted standard test exists that will distinguish between bacteria originating from man or other warm-blooded animals. It is recommended that Horry County, with agreement from SCDHEC, conduct a study designed to develop a test to determine the source of the bacteria and/or develop a correlation between the bacteria detected and the likely origin of the bacteria. If, through repetitive testing and quality control, a relationship could be established between the quick enterococcus test and the more time consuming test for origin determination could be established, it may be possible to reformulate beach warning policy while protecting public health.