**FINAL REPORT**
FOR:

# BRIARCLIFFE ACRES WATER QUALITY STUDY

**PREPARED FOR:**
**HORRY COUNTY, SC**

**J – 22072**

**January 31, 2011**

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**EXECUTIVE SUMMARY**

This study was intended to confirm or disprove a link between elevated fecal indicator bacteria concentrations in the waters around Briarcliffe Acres and the septic tank systems used as the principal means of wastewater disposal in the area. This study included data collection and assessment, septic tank system surveys, watershed assessment, and water quality sampling. Previous studies and monitoring have documented elevated fecal indicator bacteria concentrations in the surface waters (i.e. lakes, swash, and surf zone) in and around Briarcliffe Acres. Some of these studies have theorized (and was partially substantiated through limited monitoring) that the fecal indicator bacteria have a human source, most likely the septic tanks systems in the area.

An anonymous septic tank survey conducted by mail of homeowners in Briarcliffe Acres, as well as, interviews of maintenance personnel and field observations at the Meher Spiritual Center. No significant issues concerning the septic tank systems in area was identified during the survey.
A watershed assessment of the Briarcliffe Acres Swash watershed was conducted. The watershed assessment identified limited publically owned wastewater infrastructure and approximately 116 privately owned septic tank systems in the Briarcliffe Acres Swash watershed.
The watershed was determined to have a relatively low amount of developed area a very limited amount (5.4%) of impervious areas.

Water quality sampling and subsequent specialized bacteria source tracking analyses offered the most definitive evidence linking the elevated fecal indicator bacteria values to human sources. Various locations were sampled during separate dry weather and wet weather events spread over time from November 2009 to September 2010. For the dry weather events, fecal indicator bacteria levels were generally less than South Carolina water quality standards.

A significant portion of the samples collected during wet weather events contained concentrations of fecal indicator bacteria higher than standards. Specialized bacteria source tracking tests for optical brighteners and the human Bacteroides gene positively linked these bacteria to a human source mostly in the Briarcliffe Swash. Other locations in the watershed could not be positively linked to human sources. With no other indication of potential human sources, the source of a portion of the fecal indicator bacteria is from the immediately adjacent septic tank systems (generally those located between the Briarcliffe Acres lakes and swash).

**INTRODUCTION AND BACKGROUND**

During the past years, beach closings in Horry County have resulted due to high levels of bacterial contaminants being detected in the surf zone of the Atlantic Ocean. In 2000, Horry County commissioned a study (D&F, 2002) to identify sources of contamination and to recommend options for improvement to water quality at storm water outfalls to the Atlantic Ocean. In this study, it was observed:

> *"The residences throughout the Briarcliffe 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 Briarcliffe 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 Briarcliffe 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."* (D&F 2002, pg. 3.1-3.2)

The study went on to recommend:

> *<u>Provide Sewer to Briarcliffe Acres</u> - The Briarcliffe 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 Briarcliffe Acres be evaluated to determine the feasibility of connecting the homes in this community to a sanitary sewer system.* (D&F 2002, pg. 3.1-3.2)

A follow-on study (D&F, 2004) addressed several of the recommendations for additional studies from the 2002 study, but did not specifically address septic tank/sewer service for Briarcliffe Acres.

Over the past few years, a few homes in Briarcliffe Acres along the Atlantic Ocean where taken off septic tanks and provided with sanitary sewer service in cooperation with the City of Myrtle Beach. The affect of this change on water quality, and more specifically the occurrence of beach closings have not been studied. In addition, the previous sampling (D&F 2002) implicating existing septic tanks as a source of bacteria was limited. Thus, this study is aimed to confirm or disprove a link between fecal coliform concentration in the waters around Briarcliffe Acres and the septic tanks that are in use in the area.

**PROJECT DESCRIPTION**

This project was broken into five tasks as follows:

- Task 1 - Data Collection
- Task 2 - Septic Tank System Survey
- Task 3 - Watershed Assessment
- Task 4 - Water Quality Sampling
- Task 5 - Data Analysis and Report

Task 1 - Data Collection

Available mapping data was collected for the Briarcliffe Acres area. GIS mapping data was collected and used as part of the analysis and to prepare exhibits for the project. The following mapping data was collected and/or used as part of this project:

- Aerial photography (2006 and 2009)
- Historical Water Quality Monitoring Stations (SCDHEC)
- Topography (1-foot contours)
- Roads
- Sanitary Sewer Utility Infrastructure
    - Force Mains
    - Gravity Sewers
    - Manholes
    - Pump Stations
- Sanitary Sewer Service Areas
- Impervious Areas
- Building Footprints
- Soils
- Parcels

Historical water quality and other data were collected for the project area. This data included:

- Meher Spiritual Center water quality and other environmental studies (Watson, 1999; Watson, 2002; and Various, 1998)
- Briarcliffe Acres water quality testing (CCU, 2003a and CCU 2003b)
- Horry County water quality studies (D&F, 2002 and D&F, 2004)

Historical shellfish and beach surf monitoring data was also collected for stations in the immediate vicinity of Briarcliffe Acres from the EPA STORET database and SCDHEC.

Task 2 - Septic Tank System Survey

A septic tank survey of Briarcliffe Acres residents was conducted using an anonymous questionnaire that was mailed to each property owner within the Town. The results of the survey were tabulated and summarized. In addition to this, a site visit and interviews with current staff members of the adjacent Meher Spiritual Center was conducted to gather information pertaining to septic tanks on their property. Following this, the general location of know/suspected septic tanks in the study area was prepared as a GIS overlay.

Task 3 - Watershed Assessment

A limited watershed assessment of the Briarcliffe Acres Swash (contributory to White Point Swash) was conducted. The assessment included the following:

- Delineated the swash's watershed,
- Identified the principal drainage features and patterns,
- Delineated major sub-basins (including those for monitoring stations),
- Described land uses within the watershed, and
- Estimated the percentage of impervious area.

Task 4 - Water Quality Sampling

*Sampling Plan and Quality Assurance Project Plan (QAPP)*

A conceptual sampling plan had been developed as part of establishing the scope of this study. During the initial phase of this study, the sampling station and protocols were refined and a project specific QAPP was prepared. The QAPP was prepared in cooperation with the three principal study participants – Thomas & Hutton Engineering Co., Coastal Carolina University Environmental Quality Laboratory, and Virginia Polytechnic Institute and State University (Virginia Tech) Department of Crop and Soil Environmental Sciences. The QAPP was approved by the study's sponsor – Horry County, SC. A copy of the QAPP is included in Appendix A.

*Dry Weather Sampling*

Dry weather sampling was conducted for the monitoring station identified for the project on four occasions. The sampling took place on the following dates:

- 12/1/2009
- 4/27/2010
- 6/16/2010
- 7/21/2010

At each site the following field parameters where collected:

- Water Depth
- Water Flow
- Conductivity
- Temperature
- Dissolved Oxygen
- pH
- Turbidity

Grab samples were collected, preserved, and shipped for laboratory analysis. The following standard laboratory parameters were analyzed:

- Biological Oxygen Demand (BOD)
- Ammonia
- Total Suspended Solids (TSS)
- Fecal Coliform Bacteria
- Enderococci Bacteria

In addition to the standard laboratory parameters analyzed above, the following parameters were also determined for each sample:

- Volatile Suspended Solids
- Optical Brighteners (via fluorometry)
- Presence of general bacteroides gene (non-human)
- Presence of human bacteroides gene
- Presence of human esp gene
- Estimate of relative human DNA contribution

*Wet Weather Sampling*

Three (3) wet weather sampling events were conducted. The sampling was conducted following the start of an expected significant rainfall event and proceeded during and after the event. Rainfall events with anticipated rainfall in excess of 0.75 inch were targeted. Multiple grab samples were collected for each station generally over a two day period. The same field and laboratory parameters described above were analyzed for the wet weather samples.

The sampling took place on the following dates (total rainfall depth also reported):

- 11/11-12/2009 – 4.1 inches
- 7/1-2/2010 – 0.8 inches
- 9/12-13/2010 – 0.9 inches

Task 5 - Data Analysis and Report

The data collected and/or produced by the study was analyzed and summarized. Interpretations and conclusions of the data are provided. This report is preliminary and only reports a portion of the water quality sampling to be conducted under this study. Following the collection of all water quality sampling events, a draft final report will be issued for Horry County's review. A final report addressing any review comments will subsequently be produced.

**PROJECT ACTIVITIES**

Historical Data / Previous Studies

*Meher Spiritual Center*

The Meher Spiritual Center was established by Meher Baba (1894-1969) as a spiritual retreat for rest, meditation, and renewal of the spiritual life. The Center is located on approximately five hundred acres of virgin forest adjacent to the Atlantic Ocean. The Center has two fresh-water lakes (Long Pond and Alligator Pond) that appear to overflow to the wetland system behind the dune line. This wetland system in turn flows northeast towards the swash adjacent Briarcliffe Acres and ultimately to White Point Swash. Throughout the Center there are residential cabins for overnight visitors, kitchen facilities, and numerous walking trails.

The Center has sponsored studies and collected various environmental data about the surface water, ground water, noise, flora and fauna, etc. on the site. One of these studies in 1994 sampled various surface water locations and analyzed the samples for fecal coliform. The results of this study (Various, 1998) are included in Appendix B. A follow-up study to this initial 1994 water quality sampling was conducted in 1999 (Watson, 1999). An excerpt from thus study is also included in Appendix B. These studies identified high concentration of fecal coliform

concentrations is some surface waters, particularly near the north-central portion of Long Lake. Ground water samples were taken and analyzed for several water quality parameters. However, no parameters related to potential ground water contamination by septic tank effluent were analyzed.

*Town of Briarcliffe Acres*

The Town of Briarcliffe Acres commissioned two small water quality sampling studies (CCU, 2003a and CCU, 2003b). The studies sampled surface water and analyzed the samples for various constituents including fecal coliform and Enterococci bacteria. The data did show elevated fecal coliform and Enterococci bacteria concentrations in the lakes interior to Briarcliffe Acres (North and South Lakes). The results of this study are included in Appendix B.

*Horry County*

Horry County has commissioned several studies to address beach closings by SCDHEC in response to elevated levels of bacterial contaminants being detected in the surf zone of the Atlantic Ocean. One of these studies (D&F, 2002) assessed potential sources of bacterial contamination. Excerpts from this report are included in Appendix B. As discussed in the Introduction and Background section, this study identified a large human component to the bacteria contamination as measured in White Point Swash (sample taken at Briarcliffe Acres Cabana access road).

*SCDHEC Shellfish and Beach Monitoring*

SCDHEC has maintained two monitoring programs that include stations in the area of Briarcliffe Acres. SCDHEC's shellfish harvesting waters monitoring program has included a station in White Point Swash (Sta. 02-01) that has been monitored (including fecal coliform) since approximately 1989. SCDHEC has also monitored water quality in the surf zone along Horry County beach since approximately 1997. Stations in the vicinity of Briarcliffe Acres include WAC-009, WAC-009A, WAC-010, WAC-011, and WAC-012. These stations (and the others in the program) are monitored for Enterococcus bacteria. Appendix B includes a map of the SCDHEC monitoring stations and summary graphs of the fecal coliform data for Sta. 02-01 and the Enterococcus bacteria data for the beach monitoring stations. This data has shown elevated fecal coliform and Enterococcus bacteria levels on numerous occasions.

Septic Tank System Survey

An anonymous septic system survey of Briarcliffe Acres property owners was conducted. After researching septic system surveys conducted by other jurisdictions, a draft septic system survey was developed. The draft survey was circulated to the project stakeholders including Horry County, Coastal Carolina University and the Town of Briarcliffe Acres. Comments and suggestions were considered and a final 20-question septic system survey was prepared. Refer to Appendix C for a copy of the septic system survey.

Using a property owner's mailing list supplied by the Town of Briarcliffe Acres, 256 septic system surveys were mailed to the property owners on March 1, 2010. Ten (10) of the surveys were returned as un-deliverable or for other reasons. Of the 246 surveys successfully delivered (assuming all surveys not returned reached the intended addressee), 151 were completed and returned. This represents a 61% response rate.

Survey responses were recorded and tabulated. Refer to Appendix C for a tabulation of the survey responses, graphs of the percentages of responses for each question, and a listing of comments provided.

Some highlights of the survey results include the following:

- Long term property ownership (ownership more than 10-year: 66%)
- Homes have 3 (49%) to 4 (28%) bedrooms
- Homes have 3 or more bathrooms (3 or more bathrooms: 79%)
- Low home occupancy (2 or less persons per home: 70%)
- Low occurrence of noticeable problems (5% reporting a known problem with their septic system)
- High occurrence of garbage disposals which are not recommend for septic tanks systems (garbage disposals: 80%)
- Pump out frequency in excess of 3-5 year SCDHEC recommendation (every 10-years: 20%; never: 30%)

T&H coordinated with the management and maintenance staff of the Meher Spiritual Center to identify the septic tank systems on the Center's property. The Center's staff provided a hand-annotated map of the property indicating the general location of the Center's 30 septic systems (including tank and drain field locations). In additions to this, T&H staff conducted a site visit on May 18, 2010 to gather more information concerning the facilities contributing to each septic system and to observe the location of each system.

In general, the septic tank systems located on the Center serve small to moderately sized cabins that are used by overnight visitors to the Center. Some facilities are used for larger meetings and gatherings. Septic system tanks and drain fields are located very close to the structure that they serve and are in generally in cleared, natural areas (some have re-grown with native brush).

Based on the assumption that all existing homes in Briarcliffe Acres (except those served by with sewer by the City of Myrtle Beach) are served on site by a single septic tank, and the information gathered (and visually confirmed) from the Meher Spiritual Center, the location of known and suspected septic tanks was mapped in the GIS database for the project. Figure 1 illustrates the septic tanks in and around Briarcliffe Acres.

Approximately 116 septic tank systems are located in the Briarcliffe Acres Swash watershed. In addition to these, approximately 41 septic tank systems are located east of the ground water potentiometric divide. The potentiometric divide was estimated from data collected for 14 monitoring wells on the Meher Spiritual Center site (Various, 1998). Thus, it is possible that septic tank effluent traveling down gradient in the ground water could emerge as groundwater seepage to the Briarcliffe Acres or Meher Spiritual Center lakes.

Watershed Assessment

A limited watershed assessment of the Briarcliffe Acres Swash (contributory to White Point Swash) was conducted. Utilizing LiDAR derived 1-foot contours available from Horry County, the total watershed area was delineated. The sub-basins contributing to the six monitoring stations established for this study were also delineated. Table 1 describes the five monitoring stations and their contributing watersheds. Figure 2 is a watershed map of the project area.

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| Data | Source | Date |
|---|---|---|
| Major Roads | ESRI Map Data | 2008 |
| Sewer Utility Infrastructure | Horry County | 2008 |
| Parcel Boundaries & Local Road Labels | Horry County | 2009 |
| Septic Tanks & Watershed Limits | Thomas & Hutton | 2010 |
| Aerial Photography | Private Source | 2006 |

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# Briarcliffe Acres Water Quality Study

## Horry County, South Carolina

## Septic Tank Locations

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| Data | Source | Date |
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| Major Roads | ESRI Map Data | 2008 |
| Parcel Boundaries | Horry County | 2009 |
| Contours | Horry County | 2005 |
| Sampling Locations, Sub-basins, & Watershed Limits | Thomas & Hutton | 2010 |
| Aerial Photography | Private Source | 2006 |

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# Briarcliffe Acres Water Quality Study

## Horry County, South Carolina

## Watershed Map

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**Table 1**
**Monitoring Stations**

| Monitoring Station | Contributing Area (ac.) | Description |
|---|---|---|
| BA1 | 38.3 | Outfall of Briarcliffe Acres Swash to White Point Swash |
| BA2 | 69.5 | Outfall of Briarcliff Acres north lake |
| BA3 | 450.1 | Contributing wetland from the south |
| BA4 | 36.8 | Outfall of Briarcliff Acres south lake |
| BA5 | 21.2 | Upland area contributing to Briarcliff Acres north lake |
| MSC1 | 47.6 | Long Lake within the Meher Spiritual Center |

Using available GIS data, particularly National Wetland Inventory (NWI) land use data (available from the US Geological Survey) and impervious area/structure data (available from Horry County), the land uses and impervious areas within the monitoring station sub-watersheds and the overall watershed were determined. Table 2 summarizes the impervious area and land use information for the watershed.

In general, the predominant land uses are residential (mainly the Town of Briarcliffe Acres) and natural areas (including mixed forest uplands and forested/non-forested wetlands) located within the Meher Spiritual Center. The overall percent impervious of the watershed (5.4%) is very low given the urban/suburban location.

The soils within the study area were assessed. As determined by the National Resource Conservation Service (NRCS), the soils within the Briarcliffe Acres Water Quality Study area are predominantly Newham (Nh) fine sands, Lakeland (a) sand, and Leon (Le) fine sands. Refer to Figure 3 for a soils map of the study areas. Using the NRCS web-based soil survey database (http://websoilsurvey.nrcs.usda.gov), soils information for the study area was obtained. Refer to Appendix D for relative soils information from the NRCS.

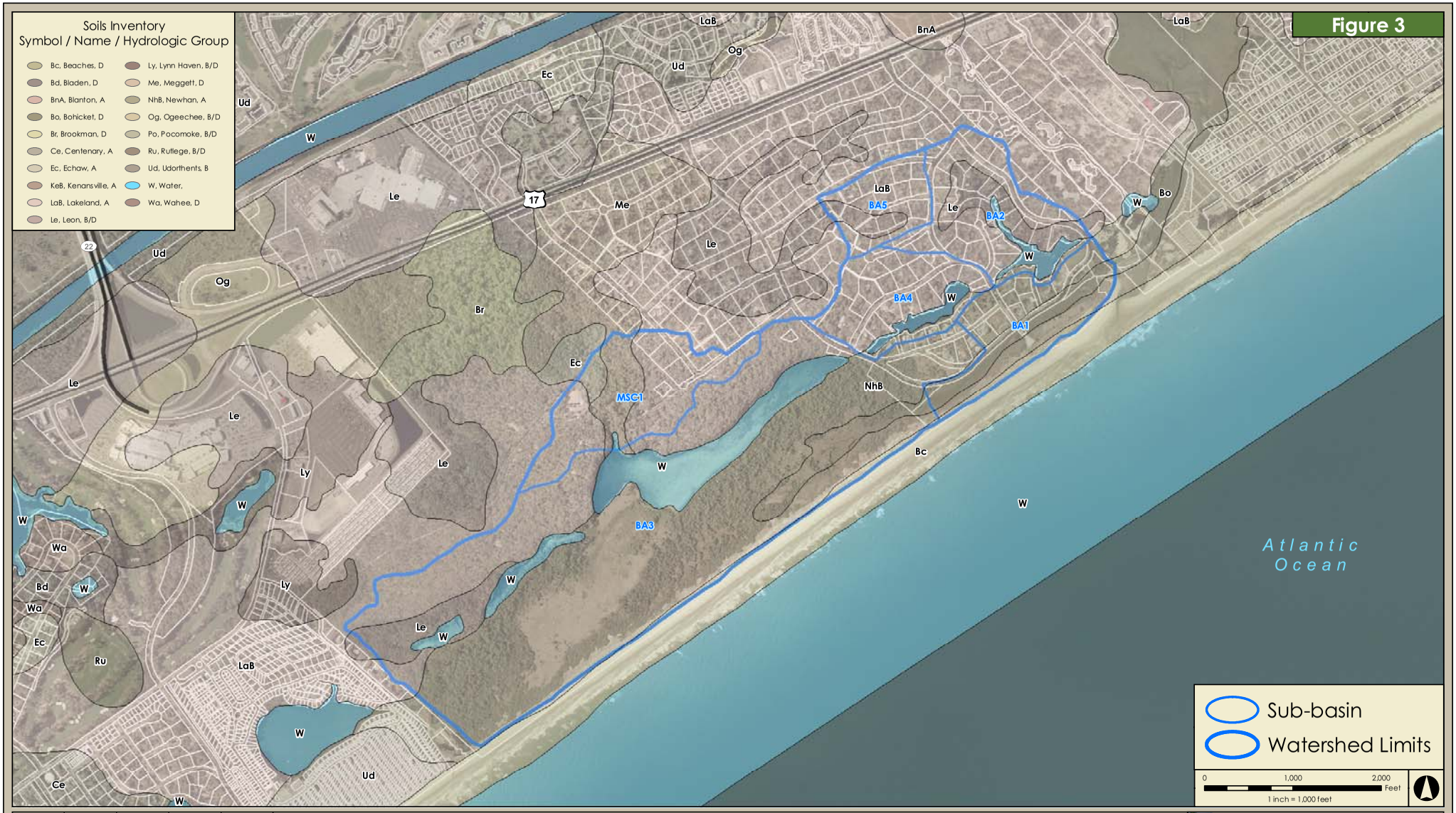
The Newham, Lakeland and Leon sands are nearly all sand (approximately 95-98%) with a very small portion of silts (2-5%). These soils also have a very high saturated hydraulic conductivity ($K_{sat}$), ranging from 42 to 141 µm/sec. The Newham, Lakeland and Leon sands are defined as "very limited" for use as septic tank adsorption fields by the NRCS. The reasons given by the NRCS for this are:

- Seepage, bottom layer
- filtering capacity
- depth to saturated zone

The NRCS rates soils for used as septic tank adsorption fields considering several factors including the absorption of the effluent, construction and maintenance of the system, and public health. In general, the predominant soils in the study area are classified as "very limited" for use as a septic tank absorption field because the seepage is too great and thus the soils may not adequately filter the effluent. Also, the depth to the saturated zone (water table) may be inadequate and not allow the effluent to break down in the unsaturated zone. As a result, the ground water may become contaminated.

**Table 2**
**Watershed Assessment**

| Sub-Basin | Area | Impervious Area | | Land Use (Modified from NWI) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Residential | | Open Water | | Mixed Upland Forest | | Forested Wetland | | Non-Forested Wetland | | Beach / Sandy Areas | |
| | (ac.) | (ac.) | (%) | (ac.) | (%) | (ac.) | (%) | (ac.) | (%) | (ac.) | (%) | (ac.) | (%) | (ac.) | (%) |
| BA1 | 38.3 | 4.2 | 10.9% | 21.5 | 56% | - | | 3.4 | 9% | - | | 3.1 | 8% | 10.3 | 27% |
| BA2 | 48.3 | 8.0 | 16.5% | 43.9 | 91% | 4.4 | 9% | - | | - | | - | | - | |
| BA3 | 296.2 | 3.5 | 1.2% | 19.1 | 6% | 34.7 | 12% | 96.9 | 33% | 41.8 | 14% | 91.6 | 31% | 12.2 | 4% |
| BA4 | 36.8 | 5.8 | 15.8% | 31.7 | 86% | 5.1 | 14% | - | - | - | - | - | - | - | - |
| BA5 | 21.2 | 3.2 | 15.2% | 21.2 | 100% | - | - | - | - | - | - | - | - | - | - |
| MSC1 | 47.6 | 1.6 | 3.3% | 15.0 | 32% | 0.1 | 0.3% | 21.8 | 46% | 10.6 | 22% | - | - | - | - |
| TOTAL | 488.5 | 26.2 | 5.4% | 152.4 | 31% | 44.3 | 9% | 122.1 | 25% | 52.5 | 11% | 94.7 | 19% | 22.5 | 5% |

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| Major Roads | ESRI Map Data | 2008 |
| Parcel Boundaries | Horry County | 2009 |
| Soils Inventory | USDA NRCS SSURGO | varies |
| Sub-basins & Watershed Limits | Thomas & Hutton | 2010 |
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# Briarcliffe Acres Water Quality Study

## Horry County, South Carolina

## Soils Map

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Water Quality Sampling

Water quality sampling was conducted according to the sampling plan and per the Quality Assurance Project Plan. As discussed in the Project Description section, three (3) wet weather and (4) dry weather sampling events were conducted.

Wet weather sampling was conducted on the following dates:

- 11/11-12/2009
- 7/1-2/2010
- 9/12-13/2010

Dry weather sampling was conducted on the following dates:

- 12/1/2009
- 4/27/2010
- 6/16/2010
- 7/21/2010

Rainfall totals for local rainfall gages during wet weather events is summarized in Table 3. Refer to Figure 4 for the location of the rainfall gages.

Refer to Appendices E and F for the water quality sampling results.

**Table 3**
**Rainfall Totals**

| Date | Daily Rainfall (in) | |
|---|---|---|
| | Grand Strand Airport | Apache Pier |
| Event 1 | | |
| 11/9/2009 | T | 0.00 |
| 11/10/2009 | 1.25 | 0.32 |
| 11/11/2009 | 3.63 | 2.89 |
| 11/12/2009 | 0.03 | 0.01 |
| 11/13/2009 | 0.04 | 0.00 |
| Event 2 | | |
| 6/29/2010 | 0.00 | 0.00 |
| 6/30/2010 | 0.20 | 0.02 |
| 7/1/2010 | 0.76 | 0.53 |
| 7/2/2010 | 0.00 | 0.00 |
| Event 3 | | |
| 9/10/2010 | T | 0.00 |
| 9/11/2010 | 0.01 | 0.02 |
| 9/12/2010 | 0.69 | 1.07 |
| 9/13/2010 | 0.00 | 0.00 |

T = trace

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# Briarcliffe Acres Water Quality Study

## Horry County, South Carolina

## Rainfall Gauges

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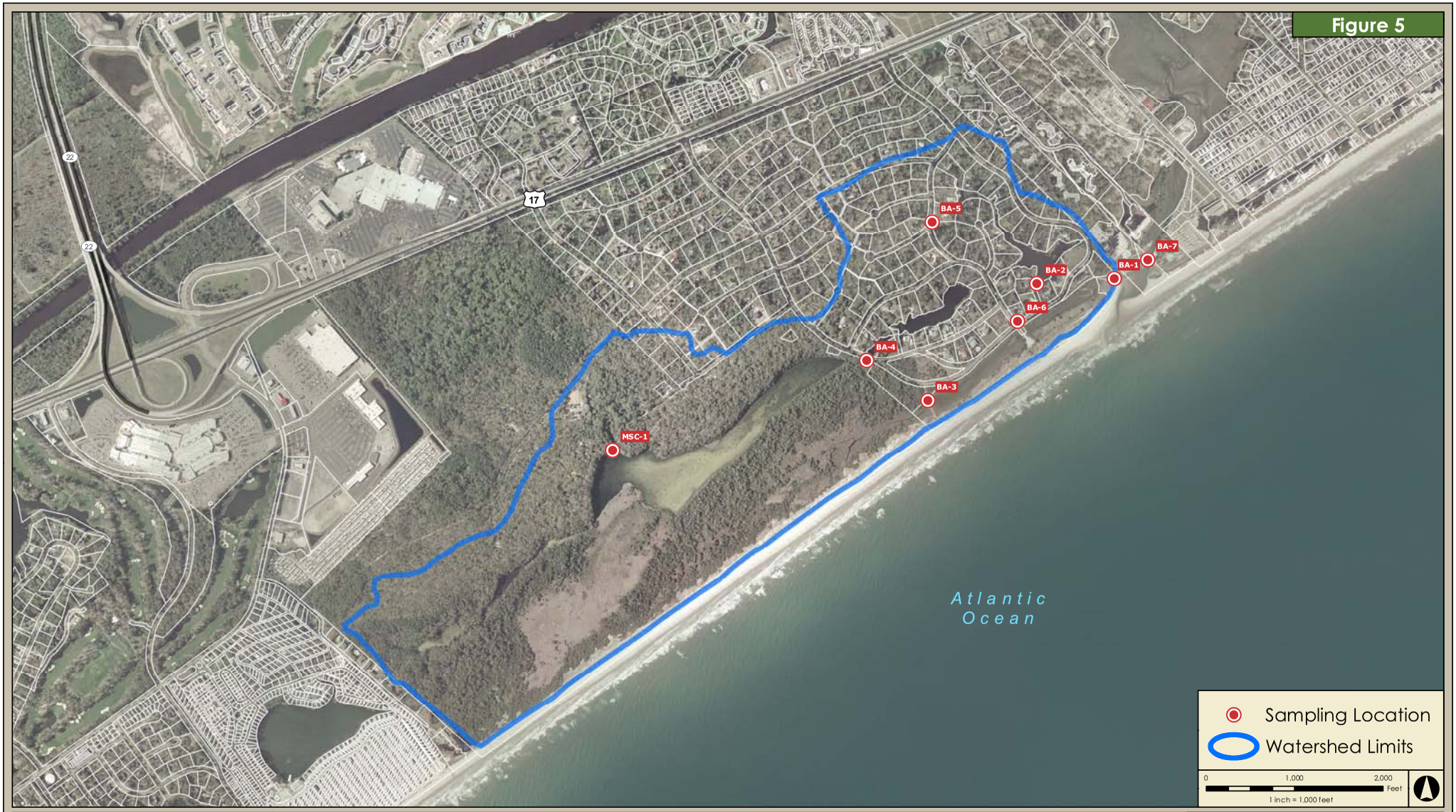
During the sampling program two minor modifications were made to the program. The first modification was to in reaction to field conditions and the second modification was to provide more data to assess the watershed conditions. The first modification involves sampling at Station BA-5, which was the interior sampling location located on contributing drainage feature upstream of the internal lakes. As anticipated during dry weather flow events, not flow was observed at the location and thus no samples were taken. During the first wet weather event (November 2009, 4.1 inches of rainfall), flow was observed and samples were taken. However during the subsequent second and third wet weather events (July 2010, 0.8 inches and September 2010, 0.9 inches) no flow was observed and thus no samples were taken.

Since sampling was not conducted a planned (see above) and based on preliminary results of previous dry and wet weather events, additional sampling locations were added to the program during the last wet weather sampling event (September 2010, 0.9 inches). The sampling locations added were:

- BA-6: roadside ditch on northwest side of Cabana Road at Beach Drive, and
- BA-7: White Point Swash at footbridge.

Figure 5 illustrates the locations of the original and new water quality sampling locations. Tables 4 and 5 are summaries of the collected water quality data for dry and wet weather events, respectively. For illustrative purposed, samples that exceed the South Carolina salt water (Class SA) quality standards for FIB ( Enterococci – 104 MPN/100 ml and fecal coliform – 400 MPN/100ml) are highlighted. In addition, specialized bacteria source tracking analytics (optical brighteners and human bacteroides gene marker) that are considered positive for a human source are also highlighted.




| Job Number: 22072 | Produced: 7/06/2010 | Produced By: RPK | Modified: | Modified By: |
|---|---|---|---|---|
| File: N:\2007\3.GIS\Briarcliffe_SampleLocations.mxd | | | | Vertical Datum: NAVD 88 |

Thomas & Hutton compiled the map information from the following sources:

| Data | Source | Date |
|---|---|---|
| Parcel Boundaries | Horry County | 2009 |
| Sampling Locations & Watershed Limits | Thomas & Hutton | 2010 |
| Aerial Photography | Private Source | 2006 |

DISCLAIMER
Where Thomas & Hutton is cited as the data source, the firm has created or verified the data. For all other sources cited, Thomas & Hutton used the data "as is." has made no independent investigation of the data, and makes no representation as to the accuracy or completeness of the data. Please see each source for available documentation of its respective datasets.
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# Briarcliffe Acres Water Quality Study

## Horry County, South Carolina

## Sampling Locations Map

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GEOGRAPHIC INFORMATION SYSTEMS
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**Table 4**
**Dry Weather Events - Results Summary**

| Date | Time | Field Sample or Site ID | Conductivity (mS/cm) | Enterococci (MPN/100mL) | Fecal Coliform (MPN/100mL) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Dissolved Oxygen (% sat) | pH (S.U.) | True Color (absorbance, PtCo) | TSS (mg/L) | VSS (mg/L) | Ammonium-N (ug/L) | *BOD (mg/L)* | Optical Brighteners | Fecal Bacteroides gene | Human Bacteroides gene | Relative human amount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Event 1** | | | | | | | | | | | | | | | | | | |
| 12/1/2009 | 12:20 PM | BA-1 | 51,700 | 85 | 130 | 2.78 | 10.67 | 104.0 | 7.91 | 15 | 48.0 | 10.2 | 39.6 | 4.108 | ND | positive | ND | none |
| 12/1/2009 | 12:42 PM | BA-2 | 384 | 41 | 130 | 1.93 | 7.02 | 67.4 | 7.40 | 40 | 22.0 | 19.2 | 102 | 4.528 | ND | ND | ND | none |
| 12/1/2009 | 12:00 PM | BA-3 | 41,400 | 407 | 625 | 4.45 | 7.22 | 67.6 | 7.63 | 50 | 32 | 8 | 42 | 3.891 | ND | positive | ND | none |
| 12/1/2009 | 12:58 PM | BA-4 | 512 | 31 | 33 | 1.14 | 6.95 | 66.0 | 7.32 | 24.5 | 7.5 | 5.6 | <7.5 | 5.038 | ND | ND | ND | none |
| 12/1/2009 | 1:35 PM | MSC-1 | 428 | 301 | 490 | 1.12 | 9.85 | 94.8 | 7.57 | 21 | 2.6 | 2.4 | 125 | 3.988 | ND | positive | ND | none |
| **Event 2** | | | | | | | | | | | | | | | | | | |
| 4/27/2010 | 1:22 PM | BA-1 | 48,800 | 37 | 41 | 6.37 | 9.07 | 105.5 | 7.85 | 16 | 10 | 2 | 103 | 1.693 | ND | ND | ND | none |
| 4/27/2010 | 3:03 PM | BA-2 | 395 | 20 | 130 | 2.47 | 11.41 | 137.3 | 8.72 | 31.5 | 5.6 | 5.1 | 25.5 | 3.355 | ND | positive | ND | none |
| 4/27/2010 | 1:37 PM | BA-3 | 42,900 | 110 | 240 | 9.01 | 7.34 | 87.5 | 7.54 | 59.5 | 34 | 10.4 | 72.7 | 3.000 | positive | positive | ND | none |
| 4/27/2010 | 2:49 PM | BA-4 | 475 | 145 | 4.5 | 2.12 | 5.08 | 59.8 | 7.54 | 33.5 | 3.5 | 2.8 | 26.9 | 2.270 | ND | positive | ND | none |
| 4/27/2010 | 2:23 PM | MSC-1 | 358 | 20 | 79 | 1.84 | 7.6 | 89.6 | 7.90 | 19 | 1.7 | 1.7 | 40.9 | 2.005 | ND | ND | ND | none |
| **Event 3** | | | | | | | | | | | | | | | | | | |
| 6/16/2010 | 5:22 AM | BA-1 | 52,600 | 839 | 1,100 | 6.04 | 3.10 | 40.0 | 7.64 | 24 | 13.4 | 4.0 | 94.8 | 3.180 | ND | positive | ND | none |
| 6/16/2010 | 6:11 AM | BA-2 | 422 | 323 | 33 | 2.85 | 4.89 | 65.9 | 7.60 | 44.5 | 6.0 | 4.8 | 38.5 | 2.785 | ND | positive | ND | none |
| 6/16/2010 | 5:51 AM | BA-3 | 51,400 | 2,603 | 2,400 | 9.54 | 1.58 | 20.4 | 7.22 | 77.5 | 18.2 | 6.8 | 78.2 | 3.118 | questionable | positive | positive | moderate |
| 6/16/2010 | 6:31 AM | BA-4 | 492 | 301 | 12 | 2.85 | 2.53 | 33.7 | 7.44 | 38.5 | 11.8 | 9.2 | 48.7 | 2.203 | ND | positive | ND | none |
| 6/16/2010 | 7:08 AM | MSC-1 | 381 | 152 | 230 | 1.87 | 8.08 | 106.7 | 8.62 | 24.5 | 4.2 | 3.4 | 85 | 1.749 | ND | positive | ND | none |
| **Event 4** | | | | | | | | | | | | | | | | | | |
| 7/21/2010 | 9:52 AM | BA-1 | 49,300 | 10 | 230 | 14.9 | 8.21 | 108.7 | 7.85 | 26 | 28.4 | 9.6 | 292 | 1.606 | ND | ND | ND | none |
| 7/21/2010 | 9:30 AM | BA-2 | 413 | 228 | 49 | 10.3 | 6.71 | 89.6 | 7.48 | 31 | 14.8 | 11.8 | 77.8 | 2.201 | ND | positive | ND | none |
| 7/21/2010 | 10:20 AM | BA-3 | 38,400 | 98 | 490 | 60.5 | 1.87 | 24.6 | 7.45 | 90.5 | 88.0 | 34.0 | 22.4 | 7.942 | questionable | positive | ND | none |
| 7/21/2010 | 9:18 AM | BA-4 | 493 | 20 | 23 | 5.22 | 1.18 | 15.2 | 7.29 | 33 | 7.4 | 6.2 | 22.8 | 3.252 | ND | ND | ND | none |
| 7/21/2010 | 10:35 AM | MSC-1 | 396 | 10 | 4.5 | 1.73 | 7.74 | 102.5 | 8.43 | 14.5 | 4.4 | 4.4 | 43.5 | 1.121 | ND | ND | ND | none |

**Table 5**
**Wet Weather Events - Results Summary**

| Date | Time | Field Sample or Site ID | Conductivity (mS/cm) | Enterococci (MPN/100mL) | Fecal Coliform (MPN/100mL) | Turbidity (NTU) | Dissolved Oxygen (mg/L) | Dissolved Oxygen (% sat) | pH (S.U.) | True Color (absorbance, PtCo) | TSS (mg/L) | VSS (mg/L) | Ammonium-N (ug/L) | *BOD (mg/L)* | Optical Brighteners | Fecal Bacteroides gene | Human Bacteroides gene | Relative human amount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Event 1** | | | | | | | | | | | | | | | | | | |
| 11/11/2009 | 8:40 AM | BA-1 | 22,600 | 14,136 | 16,000 | 10.1 | 6.78 | 74.1 | 7.47 | 90.5 | 33.2 | 11.6 | 82.4 | 2.428 | positive | positive | positive | high |
| 11/11/2009 | 5:21 PM | BA-1 | 16,545 | 22,030 | 10,700 | 14.73 | 7.49 | 75.0 | 7.61 | 112 | 41.3 | 12.6 | 82.7 | 2.516 | positive | positive | positive | high |
| 11/12/2009 | 9:21 AM | BA-1 | 18,620 | 6,488 | 1,300 | 4.92 | 6.79 | 67.7 | 7.46 | 102 | 13.2 | 4.8 | 123 | 1.913 | questionable | positive | positive | moderate |
| 11/11/2009 | 9:36 AM | BA-2 | 327 | 2,247 | 1,100 | 4.44 | 5.40 | 58.3 | 7.41 | 34 | 8.1 | 8.0 | 11.8 | 6.936 | ND | positive | ND | none |
| 11/11/2009 | 4:48 PM | BA-2 | 361 | 1,054 | 790 | 3.43 | 9.09 | 92.0 | 7.94 | 32.5 | 8.4 | 7.3 | 8.14 | 6.476 | ND | positive | ND | none |
| 11/12/2009 | 9:57 AM | BA-2 | 361 | 801 | 330 | 3.98 | 8.83 | 89.6 | 7.90 | 33 | 5.8 | 6.4 | 13.0 | 6.256 | ND | positive | ND | none |
| 11/11/2009 | 9:05 AM | BA-3 | 5,570 | 14,136 | 9,200 | 7.73 | 6.55 | 70.8 | 7.48 | 157.5 | 17.6 | 7.3 | 23.9 | 4.193 | positive | positive | positive | high |
| 11/11/2009 | 5:10 PM | BA-3 | 3,680 | 24,196 | 16,000 | 3.27 | 7.03 | 70.2 | 7.33 | 167.3 | 7.2 | 3.6 | 21.1 | 2.723 | positive | positive | positive | high |
| 11/12/2009 | 9:41 AM | BA-3 | 4,820 | 7,701 | 2,800 | 2.45 | 7.17 | 70.4 | 7.16 | 176 | 7.0 | 3.0 | 64.4 | 2.073 | ND | positive | positive | moderate |
| 11/11/2009 | 9:23 AM | BA-4 | 439 | 1,246 | 1,700 | 3.54 | 6.51 | 70.0 | 8.17 | 24.5 | 4.0 | 2.1 | 33.2 | 2.548 | ND | positive | ND | none |
| 11/11/2009 | 4:33 PM | BA-4 | 424 | 1,842 | 790 | 4.28 | 7.14 | 71.6 | 7.53 | 26 | 4.4 | 2.7 | 47.9 | 2.493 | ND | positive | ND | none |
| 11/12/2009 | 8:48 AM | BA-4 | 453 | 520 | 560 | 3.54 | 5.7 | 57.8 | 7.37 | 23.5 | 5.2 | 3.4 | 42.3 | 1.885 | ND | positive | ND | none |
| 11/11/2009 | 9:55 AM | BA-5 | 30 | 11,199 | 5,400 | 3.60 | 8.90 | 97.1 | 7.23 | 21.5 | 8.0 | 6.0 | <7.5 | 5.710 | positive | positive | positive | moderate |
| 11/11/2009 | 4:10 PM | BA-5 | 15 | 6,488 | 1,300 | 5.18 | 9.61 | 93.7 | 6.77 | 27 | 7.7 | 6.3 | <7.5 | 7.506 | questionable | positive | positive | moderate |
| 11/11/2009 | 10:15 AM | MSC-1 | 419 | 24,196 | 3,500 | 6.8 | 7.3 | 78.9 | 7.4 | 33.3 | 14.5 | 12.1 | 57.0 | 2.640 | positive | positive | positive | moderate |
| 11/11/2009 | 3:53 PM | MSC-1 | 397 | 4,884 | 1,100 | 1.15 | 7.49 | 76.8 | 7.32 | 22 | 2.7 | 2.5 | 116 | 2.093 | ND | positive | positive | low |
| 11/12/2009 | 8:30 AM | MSC-1 | 430 | 3,448 | 1,700 | 1.06 | 5.91 | 61.3 | 7.13 | 26.5 | <3.3 | <3.3 | 126 | 1.838 | ND | positive | ND | none |
| **Event 2** | | | | | | | | | | | | | | | | | | |
| 7/1/2010 | 5:52 AM | BA-1 | 44,000 | 14,136 | 9,200 | 14.1 | 3.12 | 38.1 | 7.48 | 41 | 22.2 | 6.8 | 312 | 1.891 | positive | positive | positive | high |
| 7/1/2010 | 5:38 PM | BA-1 | 47,300 | 63 | 79 | 18.2 | 7.74 | 103.1 | 7.80 | 33.5 | 37.6 | 10.0 | 296 | 2.771 | questionable | ND | ND | none |
| 7/2/2010 | 6:35 AM | BA-1 | 52,300 | 1,823 | 395 | 6.50 | 3.41 | 40.5 | 7.65 | 22.3 | 17.7 | 7.8 | 78.1 | 1.878 | questionable | positive | positive | low |
| 7/1/2010 | 6:40 AM | BA-2 | 467 | 985 | 220 | 20.9 | 2.55 | 32.6 | 7.55 | 37.5 | 51.6 | 39.6 | 99.4 | 4.751 | questionable | positive | ND | none |
| 7/1/2010 | 5:55 PM | BA-2 | 450 | 466 | 38 | 33.3 | 7.14 | 93.2 | 7.0 | 34.7 | 85.0 | 64.3 | 48.1 | 5.208 | ND | positive | ND | none |
| 7/2/2010 | 6:59 AM | BA-2 | 460 | 4,884 | 280 | 70.8 | 3.16 | 39.5 | 6.88 | 34 | 182.0 | 114.0 | 143 | 10.53 | questionable | positive | positive | moderate |
| 7/1/2010 | 6:21 AM | BA-3 | 45,700 | 12,033 | 16,000 | 3.32 | 0.17 | 2.1 | 7.49 | 139 | 78.0 | 26.0 | 213 | 7.503 | positive | positive | positive | high |
| 7/1/2010 | 5:17 PM | BA-3 | 41,700 | 2,909 | >16,000 | 58.1 | 4.09 | 53.4 | 7.51 | 117 | 87.0 | 31.0 | 23.5 | 6.231 | questionable | positive | positive | low |
| 7/2/2010 | 6:15 AM | BA-3 | 44,800 | 6,131 | >16,000 | 15.1 | 1.13 | 13.4 | 7.42 | 98.5 | 34.5 | 15.0 | 42.3 | 4.051 | positive | positive | positive | moderate |
| 7/1/2010 | 7:00 AM | BA-4 | 440 | 226 | 79 | 3.40 | 3.78 | 28.4 | 7.38 | 42 | 4.8 | 4.4 | 60.9 | 2.891 | questionable | positive | ND | none |
| 7/1/2010 | 6:23 PM | BA-4 | 501 | 262 | 23 | 10.3 | 5.31 | 69.4 | 7.46 | 34.5 | 34.0 | 27.0 | 47.9 | 2.911 | ND | positive | ND | none |
| 7/2/2010 | 7:14 AM | BA-4 | 509 | 158 | 14 | 4.23 | 2.51 | 30.8 | 7.21 | 40.5 | 23.0 | 16.0 | 69.9 | 6.191 | ND | positive | ND | none |
| 7/1/2010 | 7:35 AM | MSC-1 | 385.5 | 1,018 | 515 | 2.1 | 8.5 | 107.5 | 8.7 | 26.0 | 4.7 | 4.4 | 70.2 | 2.458 | questionable | positive | ND | none |
| 7/1/2010 | 6:54 PM | MSC-1 | 397 | 52 | 79 | 1.64 | 9.80 | 127.1 | 8.91 | 17.5 | 3.6 | 3.2 | 48.3 | 1.711 | ND | ND | ND | none |
| 7/2/2010 | 7:35 AM | MSC-1 | 405 | 84 | 46 | 1.57 | 8.08 | 100.5 | 8.63 | 21 | 2.5 | 2.5 | 51.3 | 2.351 | ND | ND | ND | none |
| **Event 3** | | | | | | | | | | | | | | | | | | |
| 9/12/2010 | 9/12/2010 | BA-1 | 49,900 | 1,150 | 560 | 8.5 | 5.86 | 104.6 | 7.695 | 29.5 | 31.1 | 18.9 | 101.4 | 1.914 | positive | positive | positive | high |
| 9/13/2010 | 9/13/2010 | BA-1 | 44,700 | 355 | 330 | 5.55 | 2.28 | 27.9 | 7.30 | 50 | 16.0 | 6.3 | 306 | 1.501 | questionable | positive | positive | low |
| 9/13/2010 | 9/13/2010 | BA-1 | 55,100 | 201 | 330 | 9.40 | 7.29 | 95.8 | 7.82 | 20.3 | 20.0 | 5.0 | 97.6 | 1.275 | questionable | positive | positive | low |
| 9/12/2010 | 9/12/2010 | BA-2 | 401 | 63 | 49 | 3.42 | 8.73 | 117.4 | 8.26 | 30.5 | 4.7 | 4.3 | 36.1 | 2.621 | ND | ND | ND | none |
| 9/13/2010 | 9/13/2010 | BA-2 | 404 | 366 | 125 | 7.94 | 6.93 | 87.8 | 7.97 | 33.0 | 17.7 | 13.4 | 63.1 | 2.008 | ND | positive | ND | none |
| 9/13/2010 | 9/13/2010 | BA-2 | 403 | 72 | 33 | 3.41 | 9.58 | 122.2 | 7.72 | 32 | 8.0 | 6.8 | 19.4 | 2.215 | questionable | ND | ND | none |
| 9/12/2010 | 9/12/2010 | BA-3 | 40,700 | 6,488 | 1,700 | 9.86 | 4.99 | 84.7 | 7.31 | 59 | 22.5 | 7.8 | 71.9 | 3.061 | positive | positive | positive | high |
| 9/13/2010 | 9/13/2010 | BA-3 | 26,700 | 583 | 230 | 8.45 | 1.15 | 13.8 | 6.91 | 162.5 | 4.8 | 1.8 | 364 | 2.561 | positive | positive | positive | moderate |
| 9/13/2010 | 9/13/2010 | BA-3 | 43,100 | 1,050 | 310 | 12.0 | 4.38 | 56.9 | 7.32 | 80.5 | 21.8 | 7.0 | 160 | 1.695 | positive | positive | positive | moderate |
| 9/12/2010 | 9/12/2010 | BA-4 | 472 | 110 | 79 | 2.70 | 7.95 | 105.0 | 7.84 | 27.5 | 3.1 | 3.0 | 14.9 | 3.161 | questionable | positive | ND | none |
| 9/13/2010 | 9/13/2010 | BA-4 | 478 | 74 | 49 | 7.69 | 4.65 | 58.0 | 7.47 | 27.5 | 9.6 | 8.2 | 13.6 | 3.801 | ND | ND | ND | none |
| 9/13/2010 | 9/13/2010 | BA-4 | 476 | 52 | 79 | 3.32 | 8.05 | 104.3 | 7.80 | 27 | 5.2 | 5.0 | 19.8 | 2.775 | ND | ND | ND | none |
| 9/12/2010 | 9/12/2010 | BA-6 | 4,020 | 5,475 | 1,100 | 3.22 | 4.67 | 66.6 | 7.20 | 41.5 | 3.2 | 1.9 | 648 | 0.741 | positive | positive | positive | high |
| 9/13/2010 | 9/13/2010 | BA-6 | 34,500 | 3,448 | 790 | 2.32 | 1.21 | 14.9 | 7.00 | 37.5 | 14.0 | 3.4 | 690 | 0.501 | questionable | positive | positive | high |
| 9/13/2010 | 9/13/2010 | BA-6 | 4,430 | 3,448 | 490 | 3.28 | 4.03 | 50.5 | 7.23 | 33.5 | 1.5 | 1.5 | 702 | 0.414 | questionable | positive | positive | high |
| 9/12/2010 | 9/12/2010 | BA-7 | 49,600 | 1,585 | 1,300 | 13.8 | 5.53 | 98.8 | 7.75 | 13 | 60.3 | 18.0 | 120 | 1.381 | ND | positive | ND | none |
| 9/13/2010 | 9/13/2010 | BA-7 | 47,500 | 620 | 490 | 7.28 | 2.50 | 30.7 | 7.52 | 17 | 2.3 | 1.6 | 326 | 0.901 | ND | positive | ND | none |
| 9/13/2010 | 9/13/2010 | BA-7 | 54,900 | 146 | 79 | 11.2 | 6.85 | 90.4 | 7.84 | 13.5 | 19.8 | 4.3 | 98.0 | 0.975 | ND | positive | ND | none |
| 9/12/2010 | 9/12/2010 | MSC-1 | 415 | 108 | 70 | 1.81 | 8.68 | 115.0 | 8.72 | 17 | 6.5 | 5.7 | 82.8 | 1.241 | questionable | positive | ND | none |
| 9/13/2010 | 9/13/2010 | MSC-1 | 419 | 228 | 110 | 2.63 | 7.64 | 93.9 | 8.46 | 17.3 | 4.4 | 5.4 | 117 | 0.761 | questionable | positive | ND | none |
| 9/13/2010 | 9/13/2010 | MSC-1 | 418 | 21 | 75 | 1.68 | 9.16 | 118.7 | 8.68 | 18 | 4.6 | 5.2 | 94.1 | 1.195 | ND | ND | ND | none |

**DISCUSSION AND CONCLUSIONS**

This study was intended to confirm or disprove a link between fecal indicator bacteria concentration in the waters around Briarcliffe Acres and the septic tank systems used as the principal means of wastewater disposal in the area. This study included data collection and assessment, septic tank system surveys, watershed assessment, and water quality sampling.

Previous studies and monitoring have documented elevated fecal indicator bacteria concentrations for surface waters (i.e. lakes, swash, and surf zone) in and around Briarcliffe Acres. Some of these studies have theorized (and partially substantiated) that the fecal indicator bacteria has a human source (i.e. septic tanks systems). An anonymous septic tank survey conducted by mail of homeowners in Briarcliffe Acres, as well as, interviews of maintenance personnel and field observations at the Meher Spiritual Center, indicate that septic tank systems in general function as intended with no obvious indications of malfunctions or failures.

A watershed assessment of the Briarcliffe Acres Swash watershed was conducted. The watershed assessment determined that there are no permitted NPDES point source discharges in the watershed and only limited public wastewater collection infrastructure. The existing public wastewater infrastructure consists of a limited amount of pressurized forcemain pipe (no gravity systems). Approximately 116 privately owned septic tank systems are located in the Briarcliffe Acres Swash watershed.

Land uses and impervious cover was assessed as an indicator of potential for non-point source runoff to be a potential source of fecal indicator bacteria. It was determined that the watershed has a relatively low amount of developed area (31% of the watershed is classified as residential, while the remainder is undeveloped). The percent impervious is very limited (5.4%), which is very low in comparison to other suburban/urban areas in the immediate area. In addition, the stormwater collection system in Briarcliffe Acres and within the Meher Spiritual Center is very limited, with only a few culverts and ditches. An assessment of soils within the watershed indicated that in general, the soils are not suitable for septic tank systems due to excessive seepage.

It should be noted that a significant source of fecal indicator bacteria was not specifically addressed by the watershed assessment. Wildlife and pets, in some cases, can be a significant source of fecal indicator bacteria. Antidotal evidence has indicates that pet sources may be minimal while wildlife sources could be large.

Water quality sampling and subsequent specialized analyses offered the most definitive evidence of the source of fecal indicator bacteria in the watershed. Five locations (BA-1, BA-2, BA-3, BA-4 and MSC-1) in the watershed were sampled four times during separate dry weather events and multiple times during three wet weather events. Three other locations (BA-5, BA-6 and BA-7) were also sampled multiple times during one wet weather event.

Of the four dry weather events, fecal indicator bacteria levels were generally less that South Carolina water quality standards (except for the June 2010 event). It should be noted that BA-3 had fecal indicator bacteria (either Enterococci, fecal coliform, or both) concentrations above the standards for all four events. In addition, the site was positive for optical brighteners and the human Bacteroides gene on separate dry weather events.

A significant number of the samples collected during the three wet weather events contained concentrations of fecal indicator bacteria higher than the standards. These elevated fecal indicator bacteria levels correlated with positive tests for optical brighteners and the human Bacteroides gene at BA-1 and BA-3 (Briarcliffe Acres Swash). The relative contribution of human attributable fecal indicator bacteria for BA-1 and BA-3 was high to moderate in most cases. The other stations (BA-2 and BA-4, Briarcliffe Acres lake outfalls and MSC-1, Meher Spiritual Center) do not indicate a correlation between elevated fecal indicator bacteria levels and positive tests for optical brighteners and the human Bacteroides gene.

Other sites (BA-5, upstream of Briarcliffe Acres lakes and BA-6, ditch adjacent Cabana road) have a correlation between elevated fecal indicator bacteria levels and positive tests for optical brighteners and the human Bacteroides gene during a single wet weather event. The relative contribution of human attributable fecal indicator bacteria for BA-5 and BA-6 were moderate and high, respectively. BA-7 (White Point Swash) did not indicate a correlation between the elevated fecal indicator bacteria levels and positive tests for optical brighteners and the human Bacteroides gene.

Based on the information and data generated for this study, especially the water quality data measured BA-1, BA-3 and BA-6, the fecal indicator bacteria concentration during wet weather events in the Briarcliffe Acres Swash can be attributed to a human source. With no other indication of a potential human source, the source of these fecal indicator bacteria is the immediate adjacent septic tank systems (generally those located between the Briarcliffe Acres lakes and swash). The generally negative correlation at BA-2, BA-4 and MSC-1, can be interpreted that the source of fecal indicator bacteria inland of the Briarcliffe Acres and Meher Spiritual Center lakes cannot be positively linked to septic tank systems.

**RECOMMENDATIONS**

The immediate priority of any future effort should be in the areas between the Briarcliffe Acres lakes and swash. Subsequent, possibly parallel, but less urgent efforts should be devoted to the area inland of the Briarcliffe Acres lakes. The following general recommendations are made:

1. All homes should connect to the adjacent sewer system, where sewer service is available, per the existing Town of Briarcliffe Acres ordinance.

2. Other Town residents that are not to be connected to the sewer system and have not pumped out their septic tank in the past 5 years should have their septic tank pumped within one calendar year and every 5 years thereafter. The Town may consider coordinating with Town residents and a local septic tank pumping company to negotiate a standard service (inspection, cleaning, pumping, etc.) for a discounted rate.

3. Residents should install water-saving devices such as low-flow toilets, showerheads, and washing machines in their homes to limit the amount of water discharges to the their septic systems. The Town may consider providing educational materials and reminders/notices to residents to consider water-saving devices during repairs, remodeling, and new appliance purchases.

4. All residents should be educated on the proper use and care of their septic systems. The Town may consider coordinating this education through collaboration with other outreach entities (SCDHEC, Horry County, Coastal Carolina University, Clemson University – Carolina Clear, etc.).

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# QUALITY ASSURANCE PROJECT PLAN

**FOR**

# BRIARCLIFF ACRES WATER QUALITY STUDY HORRY COUNTY, SC

**PREPARED FOR**

**HORRY COUNTY, SC**

**FINAL DRAFT**
**JANUARY 13, 2010**

**J – 22072.0000**


THOMAS & HUTTON ENGINEERING CO.

SAVANNAH, GEORGIA ◆ BRUNSWICK, GEORGIA
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# QUALITY ASSURANCE PROJECT PLAN

# FOR

# BRIARCLIFF ACRES WATER QUALITY STUDY
# HORRY COUNTY, SC

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| Coastal Carolina University Environmental Quality Lab: | Susan Libes, Ph.D. | Date |
| Virginia Polytechnic Institute and State University, Department of Crop and Soil Environmental Sciences: | Charles Hagedorn, Ph.D. | Date |

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## 1.0 Distribution List

Horry County, South Carolina:
Tom Garigen, Stormwater Manager
Thomas & Hutton Engineering Co.:
Richard Karkowski, P.E., P.H., Project Manager
Coastal Carolina University, Environmental Quality Lab:
Susan Libes, Ph.D., Principal Investigator
Coastal Carolina University, Environmental Quality Lab:
Joe Bennett, EQL Director
Virginia Polytechnic Institute and State University, Department of Crop and Soil Environmental Sciences:
Charles Hagedorn, Ph.D., Bacteria Source Tracking Specialist

## 2.0 Project Organization

Project Sponsor:
Horry County, South Carolina
Tom Garigen, Stormwater Manager
Project Coordination, Management and Report Production:
Thomas & Hutton Engineering Co.
Richard Karkowski, P.E., P.H., Project Manager
Water Quality Principal Investigator:
Coastal Carolina University, Environmental Quality Lab:
Susan Libes, Ph.D., Principal Investigator
Water Quality Sampling and Laboratory Coordination:
Coastal Carolina University, Environmental Quality Lab:
Joe Bennett, EQL Director
Bacteria Source Tracking Analysis Coordination:
Virginia Polytechnic Institute and State University, Department of Crop and Soil Environmental Sciences:
Charles Hagedorn, Ph.D., Bacteria Source Tracking Specialist

## 3.0 Project Definition / Background

Refer to Appendix A.

## 4.0 Project / Tasks Description

Refer to Appendices A and B.

## 5.0 Data Quality Objectives and Criteria for Measurement Data

The main objective of this monitoring program and study are:

- Document historic data and information related to elevated bacteria levels in the swash adjacent the Town of Briarcliff Acres and the adjacent Atlantic Ocean.
- Document the relative number and location of septic systems within the Town of Briarcliff Acres.
- Document the watershed of the swash adjacent the Town of Briarcliff Acres and describe potential sources and characteristics related to bacterial contamination.
- Collection of water samples and analyze for the specified parameters to determine the presence and concentration of indicator substances for bacteria and pathogens contamination.
- Determine the relative contribution of human and non-human sources of bacteria loading found in the water samples.

The ultimate goal of this monitoring program and study is to identify or disqualify septic tank systems located in the watershed as a significant source of bacteria loading in the watershed.

Once collected, the data from this study will be used to:

- Identify the relative location of bacteria loading sources in the watershed.
- Identify potential sources – human or non-human – of bacteria loading.

## 6.0 Special Training Requirements/Certifications

No special training requirements and/or certifications will be required for this project.

## 7.0 Documentation and Records

All sampling locations (see Appendix B) were located and documented during a field orientation conducted on November 5, 2009. All sites will be sampled per the Scope of Services (Appendix A). Any deviation from the locations described in the Scope of Services (Appendix A), Sample Location Map (Appendix B), or as described in the field orientation shall be identified on the field sample collection log.

All sampling activities will be documented through the use of a field sample collection log. The log will record weather, tidal flow, field measurements (e.g. pH, salinity, water temperature, DO, conductivity, etc.) and data pertinent to the collection of samples such as type of sample, time collected, samplers, and the type, number, and volume of sample containers, and preservation technique.

Analytical results, in hard copy form, will be maintained by each laboratory performing the analysis for a period of five (5) years. This period of time is in accordance with the requirements

and conditions of laboratory certification from the South Carolina Department of Health and Environmental Control (SCDHEC) and the National Environmental Laboratory Accreditation Program (NELAP).

## 8.0 Sampling Process Design

The sampling locations were initially located as part of preparing the Scope of Work (Appendix A) and are shown in the Sampling Location Map (Appendix B). The sites were subsequently revised following coordination with the adjacent Meher Baba Spiritual Center and during the field orientation conducted November 5, 2009. The final sites selected for sampling are described in the Scope of Work (Appendix A) and shown on the Sampling Location Map (Appendix B).

## 9.0 Sampling Methods Requirements

At each sampling location and for each grab sample collected, the following field sampling methods will be used:

Record the following in the field sample collection log:

- Collection Date and Time
- Tidal Stage
- Samplers
- Wind Direction
- Water Depth
- Water Flow (estimated)

Measure the following per the CCU EQL Standard Operating Procedure (SOP) No. 402 (Appendix C) and record in the field sample collection log:

- Specific Conductance
- Salinity
- Temperature
- Dissolved Oxygen
- pH

Collect laboratory samples for each of the following utilizing the appropriate SOP's listed:

- Turbidity – CCU EQL SOP No. 405 (Appendix D) or 406 (Appendix E)
- Biological Oxygen Demand - CCU EQL SOP No. 430 (Appendix F)
- Ammonia - CCU EQL SOP No. 447 (Appendix G)
- Total Suspended Solids - CCU EQL SOP No. 435 (Appendix H)
- Fecal Coliform Bacteria - CCU EQL SOP No. 502 (Appendix I)
- Enterococci Bacteria - CCU EQL SOP No. 501 (Appendix J)

- Optical Brightener Measurement by Fluorometry (Appendix K)

  Note that optical brightener measurements being conducted by CCU are to be considered provisional, since their SOP is being refined and is currently in draft form. Virginia Tech is conducting similar analyses and the CCU results shall only be used for comparison and validation.

Collect laboratory samples for bacteria source tracking analysis as described in Appendix L for the following:

- *Bacteroides* DNA primer
- esp *Enterococcus* human DNA primer
- Optical Brighteners

## 10.0 Sample Handling and Custody Requirements

Sample handling will be in accordance with standard, accepted field collection methods and shall meet all the requirements of the referenced SOPs. The CCU field sampling team that collects the samples will be responsible for initiating the Chain-of-Custody (COC) documentation by starting a COC form for samples to be transported to the CCU EQL and a separate COC form for samples to be shipped to the Virginia Polytechnic Institute and State University (VT) laboratory.

Each laboratory is responsible for completing the COC form as samples are received. A copy of the completed COC forms shall be provided to the Project Coordinator when analytical results are submitted by the laboratories.

## 11.0 Analytical Methods Requirements

Refer to the appropriate SOP (listed in Section 9.0) of the various parameters measured for the analytical methods requirements.

## 12.0 Quality Control Requirements

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the quality control requirements.

## 13.0 Instrument/Equipment Testing, Inspection, Maintenance Requirements

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the instrument/equipment testing, inspection, and maintenance requirements.

## 14.0 Instrument Calibration and Frequency Requirements

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the instrument calibration and frequency requirements.

## 15.0 Inspection/Acquisition Requirements for Supplies and Consumables

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the inspection and acquisition requirements for supplies and consumables.

## 16.0 Data Acquisition Requirements (Non-Direct Measurements)

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the data acquisition requirements.

## 17.0 Data Management

A field sampling collection log will be maintained and will be used for documenting the collection of field sampling measurements and the collection of grab samples for subsequent laboratory analysis. The log will record the sampling day, time of day at each station, weather conditions, field measurements, grab samples collected, and any special notes of potential importance such as unusual conditions. No special data reduction or reporting will be needed for this project. All results from field and laboratory analysis will be provided to the Project Coordinator in hard copy form (using the laboratory's standard reporting format) and in electronic form in a computer database (i.e. MS Excel) such that data retrieval may be organized as necessary.

## 18.0 Assessments and Response Actions

After each sampling and analysis event, project personnel will review the information generated to assess its usability to meet project objectives. Any suggested change or refinement of a project activity to assure that project data quality and usability objectives are met will be made to the Project Coordinator. The suggested change or refinement shall be communicated promptly to the Project Coordinator so that the suggestion can be incorporated in the project, if appropriate. The Project Coordinator will assess the suggestion and will communicate the inclusion of the suggestion to the appropriate parties. Any project related documentation will be updated by the Project Coordinator and forwarded to the project team as needed.

In the event that a problem is identified during a particular activity, a corrective action will be formulated and implemented without the approval of the Project Coordinator. Proper documentation will be made of the corrective action.

## 19.0 Reports to Management

At the conclusion of the project, Thomas & Hutton Engineering Co. will prepare a report for distribution (with input from CCU and VT as needed). The report will present a narrative of all project activities, results of all data generating activities, and an interpretation of the results, conclusion, and other recommendations. A preliminary copy of the report will be presented to Horry County (and other stakeholders) for review prior to the publication of the final report.

## 20.0 Validation and Verification Methods

Refer to the appropriate SOP (listed in Section 9.0) for the various parameters measured for the validation and verification methods to be used.

## 21.0 Reconciliation with User Requirements

A review of each sampling events' data will be conducted when the data becomes available. The review will focus on the stated project goals (listed in Section 5.0).

# Appendix A

## SCOPE OF WORK

# SCOPE OF SERVICES

**Introduction and Background**

During the past years, beach closings in Horry County have resulted due to high levels of bacterial contaminants being detected in the surf zone of the Atlantic Ocean. In 2000, Horry County commissioned a study by Davis & Floyd (D&F) to identify sources of contamination and to recommend options for improvement to water quality at storm water outfalls within the study area (*Storm Water Outfall Study – Horry County Beaches;* D&F, February 2002). In this study, it was observed:

> *"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."* (D&F 2002, pg. 3.1-3.2)

The study went on to recommend:

> *<u>Provide Sewer to Briarcliff Acres</u> - 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.* (D&F 2002, pg. 3.1-3.2)

A follow-on study was conducted by D&F in 2004 (*Atlantic Intracoastal Waterway/Atlantic Ocean Surf Bacteria Investigation,* D&F, December 2004) that addressed several of the recommendations for additional study made in the first (2002) study, but did not address septic tank/sewer service at Briarcliff Acres.

In the past few years, several homes along the Atlantic Ocean where taken off septic tanks and provided with sanitary sewer service. The affect of this change on water quality, and more specifically the occurrence of beach closings have not been studied. In addition, the previous sampling implicating the existing septic tanks was limited.

Thus, this study is aimed to confirm or disprove a link between fecal coliform concentration in the waters around Briarcliff Acres and septic tanks in the area.

Our scope of services will include the following tasks:

Task 1 - Data Collection
Task 2 - Septic Tank System Survey
Task 3 - Watershed Assessment
Task 4 - Water Quality Sampling
Task 5 - Data Analysis and Report

**Task 1 - Data Collection**

Thomas & Hutton (T&H) will gather available data and mapping of the Briarcliff Acres area. T&H maintains an extensive in-house database of geographical data (aerials, contours, sewer and water infrastructure, roads, etc.). However, we will confirm the availability of more recent data and obtain it for use in the study if readily available.

T&H will also make contact SCDHEC Onsite Wastewater Management Division (both locally and in Columbia) and other agencies (Waccamaw COG, City of Myrtle Beach, Grand Strand Water and Sewer Authority, etc.) to collect any data relative to the situation and document information pertinent to the study (sewer system services and location of facilities, septic tank permits and/or records, etc.)

Historical water quality and other data will be collected. At this time, the known sources of this data include *Storm Water Outfall Study – Horry County Beaches;* D&F, February 2002; *Atlantic Intracoastal Waterway/Atlantic Ocean Surf Bacteria Investigation,* D&F, December 2004; data collected by the Coastal Carolina University Environmental Quality Laboratory in 2003; and 1997 to present beach monitoring data by Coastal Carolina University. Other data, such as local rainfall data will also be collected from readily available sources.

**Task 2 - Septic Tank System Survey**

T&H will meet with Briarcliff Acres officials and/or residents to inform them about the study, gather information concerning existing septic tanks (size, location, service interval, known problems, etc.), and gage support for potential future recommendations (connection to sewer system). T&H will prepare materials and submit to Horry County for review and approval prior to the meeting issuing.

Following the meeting, T&H will estimate the general location of the septic tanks in the study area and prepare a GIS overlay to catalogue the know/suspected septic tank locations.

**Task 3 - Watershed Assessment**

A limited watershed assessment of the swash draining Briarcliff Acres to the Atlantic Ocean will be conducted. A preliminary delineation of the watershed is shown in Exhibit 1. The watershed assessment will establish the watershed limits, define principal drainage features and patterns in the watershed (ponds/lakes, major culverts, wetlands, swashes, etc.), delineate major sub-basins,

identify homes served by septic tanks and by sanitary sewer collection system, and describe land uses and impervious land cover percentages.

**Task 4 - Water Quality Sampling**

*Sampling Plan and Quality Assurance Project Plan (QAPP)*

A conceptual sampling plan has been established as part of developing the scope of this study. However, the study plan has to be finalized with the study stakeholders and details must be finalized. In addition, a project specific QAPP must be prepared to ensure all sampling and laboratory testing will be defensible. The conceptual sampling plan is described in the two sections below and include dry and wet (storm event dependent) weather sampling. All sampling and standard laboratory analyses will be conducted by Coastal Carolina University – Environmental Quality Lab (DHEC Certified).

The preliminary sampling locations are illustrated in Exhibit 1. The preliminary sampling locations include:

BA-1: Outfall of the swash to draining Briarcliff Acres to the Atlantic Ocean.
BA-2: Outfall of interior Briarcliff Acres lake to the adjacent lake/wetland.
BA-3: Contributing wetland from the southwest.
BA-4: Outfall of second interior Briarcliff Acres lake.
BA-5: Interior sampling location, located on contributing drainage feature upstream of second interior Briarcliff Acres lake.
MSC-1: Interior lake sampling location at Meher Spiritual Center.

*Dry Weather Sampling*

Each station (excluding BA-5) will be sampled at periodic times (for a total of 4 samples each). The stations will be sampled on the same day and as close in time as possible. Samples will be collected as close to low tide as possible to minimize the effect of tidal back flow. The water at each site will be tested for a series of field parameters including:

- Water Depth
- Water Flow (estimated)
- Specific Conductance
- Salinity
- Temperature
- Dissolved Oxygen
- pH
- Turbidity

Grab samples will be taken, preserved, and shipped for laboratory analysis. The following laboratory parameters will be analyzed (by Coastal Carolina University - Environmental Quality Laboratory):

- Biological Oxygen Demand
- Ammonia
- Total Suspended Solids
- Surfactants (optical brighteners via fluorometry)
- Fecal Coliform Bacteria
- Enderococci Bacteria
- Bacteria Source Tracking Test – human vs. non-human via the human *Bacteroides* DNA marker and the *esp* human *Enterococcus* DNA marker test. *

* Note: Dr. Chuck Hagendorn at Virginia Tech University, a known expert in the field will conduct the tests. The tests will indicate the relative percentage of bacterial from human and animal sources.

*Wet Weather Sampling*

Three (3) wet weather sampling events will be conducted. The sampling will be conducted immediately following the start of a rainfall event and proceed during and after the event. Rainfall events with anticipated rainfall in excess of 0.75 inch will be targeted.* Three grab samples will be collected for each station after the start of the rain event.

The same field and laboratory parameters will be analyzed for each wet weather grab sample as for the dry weather samples.

**Task 5 - Data Analysis and Report**

The data produced from the study will be summarized and analyzed. Any conclusions that can be derived from the data as to the amount and source of fecal bacteria contamination in the watershed will be provided.

A draft report detailing the study procedures, findings and recommendations will be prepared. The report will include details of the data collection, septic tank survey, and water quality sampling. The draft report will be reviewed with Horry County, and based on the County's comments; a final report will be produced.

*Note: Subsequent to the development of the scope of work, it was decided that the project director (T&H) and field sampling manager (CCU) would work collaboratively before imminent rain events to decide to initiate a sampling event.