ULTRAVIOLET DISINFECTION FOR STORMWATER TREATMENT IN COASTAL CAROLINAS

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BACKGROUND

South Carolina's beaches are vital resource to the state from a tourism standpoint as well as for environmental sustainability. As the coastal area has seen dramatic urbanization, storm water runoff has contributed to beach closures due to excessive pollutant buildup and runoff. The recent passage of the Beaches Environmental Assessment and Coastal Health (BEACH) Act has also brought increased levels of scrutiny to recreational coastal waters.

Ultraviolet (UV) light has been used successfully in the treatment of drinking water, wastewater and, in selective areas, storm water. UV light penetrates an organism's genetic material (DNA and RNA) and disrupts its ability to reproduce. Because it is a physical process, it eliminates the need for hazardous chemicals and there is no residual effect harmful to humans or aquatic life. Its effectiveness, though, is greatly influenced by turbidity, total suspended solids (TSS) and the UV dosage achieved.

In 2005, a pilot project funded through a grant from the National Oceanic and Atmospheric Administration (NOAA), U.S. Department of Commerce and the South Carolina Department of Health and Environmental Control (SCDHEC) was initiated to test the effectiveness of a UV treatment system at a storm water detention pond in the community of Murrells Inlet, South Carolina. This pilot project was terminated prior to concluding the testing process, thereby creating a need to look for another site for continued testing.

In 2008, Horry County, through its Storm Water program, initiated the efforts to identify a suitable site for additional testing, with the premise that the site would be considered as a permanent treatment facility operated and maintained by Horry County Storm Water staff.

The consultant team of HDR Engineering Inc. of the Carolinas (HDR), PBS&J, and the Environmental Quality Lab (EQL) in the Burroughs & Chapin Center for Marine and Wetland Studies (B&C CMWS) of Coastal Carolina University (CCU) assisted Horry County with site evaluation, design, construction of the UV facility, and testing/sampling. EQL is providing field and analytical services for this project. The facility is a stormwater detention pond in an oceanside, privately-owned campground (Pirateland Campground) just south of Myrtle Beach State Park, South Carolina. For this assessment, measurements are being made in one pond (Blue Heron) in the Pirateland Campground, with additional measurements taken in adjacent campground (Lakewood Campground) that contains a pond with no UV treatment. Simultaneously, water quality monitoring is being conducted at a larger pond without a UV treatment system in Lakewood Campground to both determine if treatment may be advisable there and to assist in evaluating the UV treatment system at Blue Heron Pond.

PROJECT OBJECTIVES

The general hypothesis being tested is that the construction and implementation of a UV treatment Best Management Practice (BMP) at a stormwater detention pond in a campground will result in a reduction of polluted runoff to the adjacent ocean. To test this hypothesis two general sampling approaches will be used:

> (1) Intensive wet weather, multiple days, sampling after significant rainstorms at the ponds before and after BMP installation to obtain a quantitative estimate of the removal of pollutants after storms. Sampling sites will be downstream of the ponds. Potential pollutants to be evaluated are: (1) contaminant bacteria, (2) sediments, (3) chlorophyll, (4) nutrients, and (5) oxygen-demanding substances.
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> (2) Wet and dry weather, single day, sampling events before, during, and after installation of the UV treatment facility to track trends in water quality in the ponds. Sampling sites will be downstream of the ponds. Results collected prior to BMP installation will be compared to those collected following installation. All of the results will be compared to federal, state, and other applicable evaluation or regulatory criteria established for estuarine and coastal marine environments. Although it is unlikely that the UV facility will cause substantial water quality improvements in nearby receiving waters of the Atlantic Ocean, comparison of all measurement results to regulatory criteria would be valuable to both quantify the magnitude of problems that exist and the potential for UV treatment to rectify such problems.

Site Selection

Site selection began through preliminary discussions between Horry County Storm Water staff and the property management staff of the Pirateland Campground. In addition the concerns of public safety with the facility in an area visited by a high volume of people (including children), as well as the need to identify a site that would be conducive to long-term use, the following criteria for siting of the facility was considered:

- Pond surface area, volume and characteristics of the surrounding drainage area,
- Evidence or knowledge of bacteria problems and/or the extent of problems,
- Inlet and outlet configuration and relationship to upstream/downstream water bodies
- Site access, ownership, and availability of utilities

Past knowledge of Horry County regarding the presence of bacteria in the receiving waters through the campground allowed this site to be a candidate for testing and treatment. A site visit by the Horry County Storm Water Manager and HDR staff evaluated the series of ponds present along the water course upstream of the ocean outfall, and adjacent to the Lakewood Campground pond outlet. The existing swash that combines the runoff from the two campgrounds prior to the ocean interface did not provide an ideal location for the facility. The next pond upstream of the confluence of the two streams had several constraints eliminating it from consideration. The next pond in the series was selected as it provided more opportunity to meet the above criteria. Figure 1 represents an aerial photo of the campgrounds and the pond connectivity. Figure 2 is the selected pond for UV treatment.

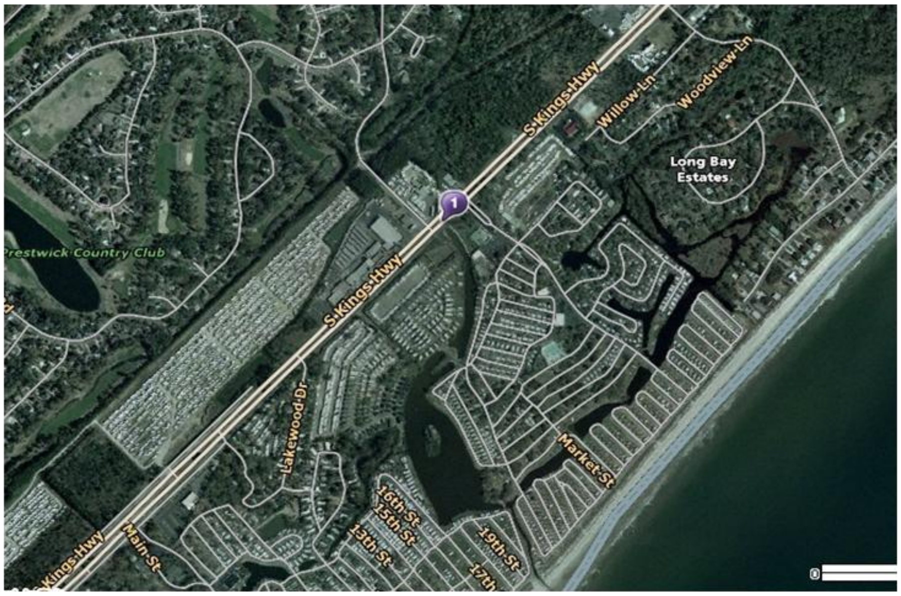

Figure 1 – Aerial View of Campgrounds and ponds selected for analysis


Figure 2 –Blue Herron Pond.

Baseline Conditions

Prior to construction of the UV Facility, water quality sampling was conducted to establish a baseline condition. This sampling was conducted for Blue Heron pond as well as the Lakewood pond. Sampling activity by EQL occurred from January 2008 through November 2008. Sampling was performed during periods of dry and wet weather, resulting in three dry periods (i.e. no rain 72 hours prior to sampling), and ten wet periods. Rainfall depth varied from less than 0.1 inch to more than 1.4 inches. From April 2008 through August 2008 the swash was also sampled to understand the result of mixing of the two pond outlets.

In summary, field measurements during the baseline period of record indicate the following:

- Enterococci bacteria concentrations in outlet waters of the ponds vary substantially from less than 10MPN (most probable number)/100mL to over 1000 MPN/100mL.
- Frequent occurrences exceeded the SCDHEC swimming advisory level for a single sample (i.e. 104MPN/100mL), with no detectable seasonal trend.
- Enterococci concentrations at the pond outlets are generally highest immediately after heavy rain and decrease after rain and consequent runoff ceases.
- Turbidity levels were generally higher in the spring and summer, with the highest levels reported during/after a storm event recording values in excess of 20 NTU.
- Dissolved oxygen levels showed the lowest levels from June through August 2008 with a range of 6.4mg/L to 9.9mg/L.
- Chlorophyll a levels indicate the pond is highly eutrophic (greater than 20 ug/L) with the pond outlet reporting less than 20ug/L only once (May), and typically in the range of 30-40ug/L.
- pH levels are in the SCDHEC standard range of 6.5 to 8.5.

Facility Description and Testing Program

The UV Facility site was chosen on the pond shown in Figure 2 to be located near the boathouse which handles canoe and paddleboat rentals for the campground. This site location (shown with a blue triangle in Figure 3) was in proximity to roadways for construction equipment access, away from active camp sites, near an available power source, and found to be practical for security and safety reasons.

The Blue Heron Pond has a surface area of approximately 2.4 acres and is on average 4 feet deep, which creates about 3 million gallons of water. The main inflow to the pond is from the northeast, with the outlet under the Pirateland Trail roadway to the south. Upon completion and operation of the facility it was observed that an existing pipe under Pyatt's Pond road in the upper portion of Figure 3 allowed water to enter the cove on the back side of the Facility, thereby create some minor short circuiting. The inlet and outlet of the pond are disconnected to upstream or downstream water bodies, which also can contribute to skewed treatment efficiencies. The yellow arrow points to the intake structure for the withdrawal of "untreated" pond water, while the beige cross illustrates the location of the outlet "diffuser" device.

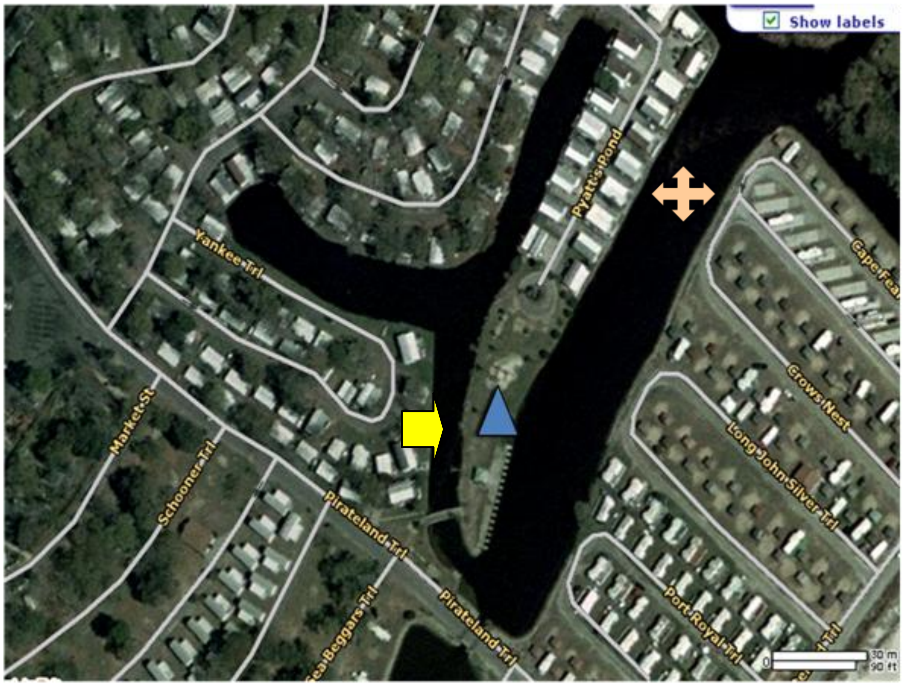

Figure 3 –Blue Herron Pond, and Locations of UV Treatment Components.

The facility's UV treatment system consists of a packaged UV disinfection unit with control interface, UV intensity sensor, magnetic flow meter, turbidity meter, pump, and data logger. The pump is located underground in a dry well adjacent to a raised platform deck that contains the UV units. The pump supplies water through a two UV units in series. A diffuser box is located on the front of the UV unit to allow the pressure flow to enter the UV unit by gravity laminar flow. The system is designed for one unit to be on, with the second unit in series as a back up. However, the second unit could be run as well as should the County desire higher intensity of bacteria elimination. The unit discharges by gravity to an upper end of the pond via a single HDPE pipeline that is anchored to the floor of the pond with two smaller HPDE concrete-filled pipes for anti-flotation. The end of the discharge pipe contains a diffuser tee to disperse the treated water across the width of the pond and minimize lake bed sediment disturbance.

The testing protocol established for the initial year (found in the Appendix) consisted of the following:

Initial Phase – Full power on a continuous basis, with daily logging of flow and intensity, and sampling during wet weather events.

Second Phase (Re-baseline) – UV unit turned off, with sampling during wet weather to compare to baseline conditions.

Third Phase and subsequent phases – alternate on an off through summer and fall to observe seasonal variations.

Figure 4 – Side View of UV Units prior to fence enclosure

Figure 5 – End View of UV unit showing intake and outlet piping, and pump station

EVALUATION OF UV SYSTEM TREATMENT

While the UV system was treating the pond water in Pirateland Campground, time-series samplings after four rainstorms were conducted in both campgrounds between April 2009 and December 2009. Bacteria concentrations at the Pirateland pond were low compared to concentrations in the Lakewood pond but sufficient to calculate enterococci decrease rates from the time-series record for the pond (Figures 6 to 9). It should be noted, however, the treatment capacity of UV treatment system is about 1 million gallons per day and is designed to be able to treat the water in the individual pond (i.e., Blue Heron Pond) where it is installed in less than a week (i.e. complete turnover of pond volume in 3-4 days). It would take the UV system several weeks or more to treat water in the entire drainage basin in Pirateland Campground. This means that after very heavy rainstorms (i.e., category 3 storms) with their rapid and large runoff flows, Blue Heron Pond is not acting as a closed system, and the later samples in time-series of samplings are likely to be untreated (or less than fully treated) water from far upstream in the drainage basin. Water flowing into the upstream end of Blue Heron Pond during the June 2009 and December 2009 storms was found to be highly contaminated with bacteria. For this reason the bacteria decrease rates estimated for these storms, especially the very heavy rainstorms, have large uncertainties.

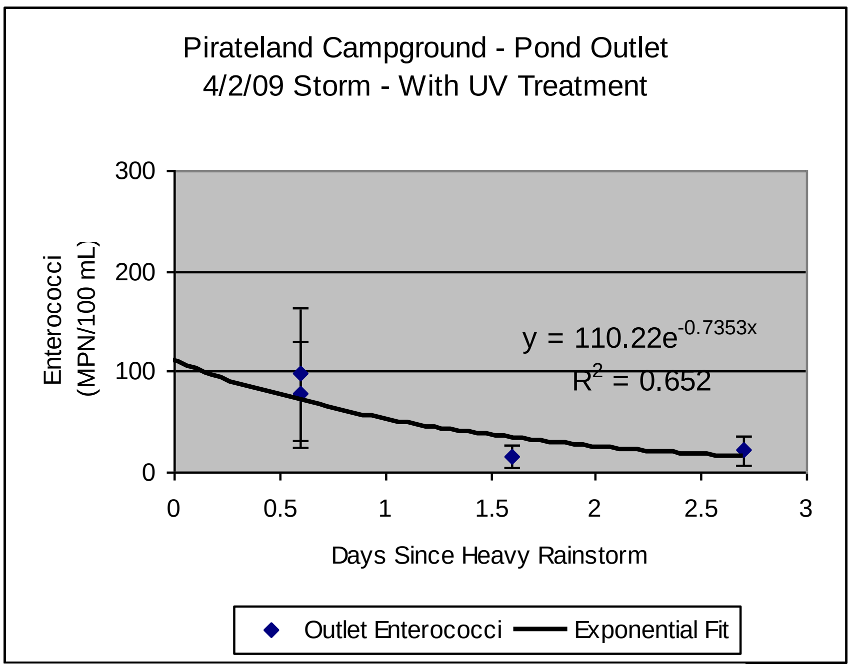

Figure 6 – UV Treatment during 0.9 inch rain

Figure 6 indicates exponential fit of enterococci bacteria concentrations at outlet of Pirateland Campground Pond after April 2009 (0.9 inch) rainstorm. Error bars indicate approximate 95% confidence limits of data points.

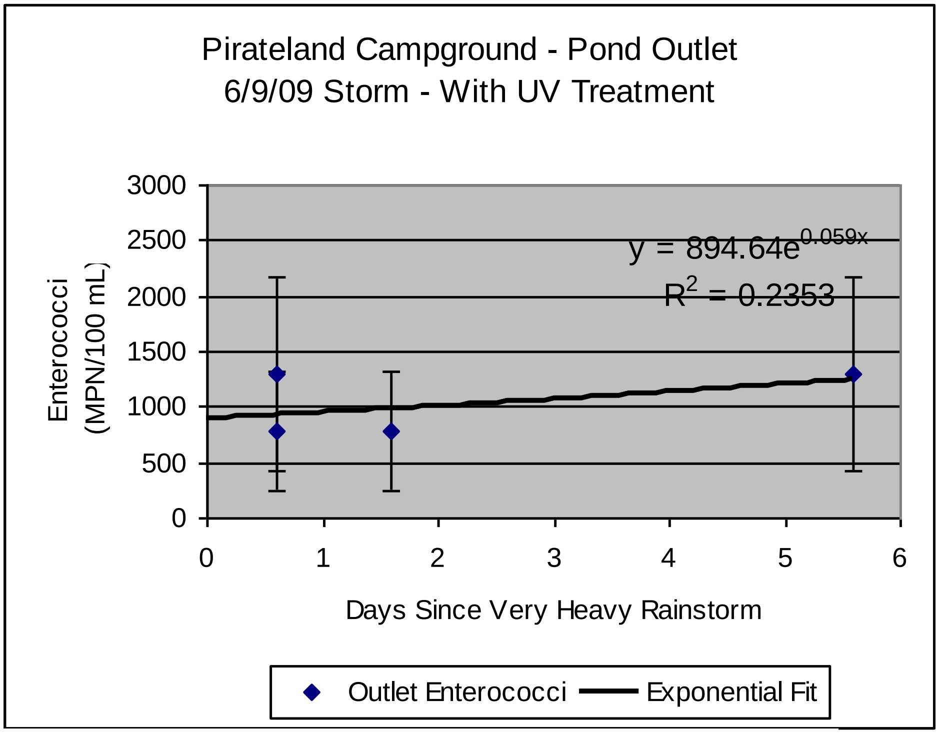

Figure 7 – UV Treatment during 2.2 inch rain

Figure 7 indicates exponential fit of enterococci bacteria concentrations at outlet of Pirateland Campground Pond after June 2009 (2.2 inch) rainstorm. Error bars indicate approximate 95% confidence limits of data points.

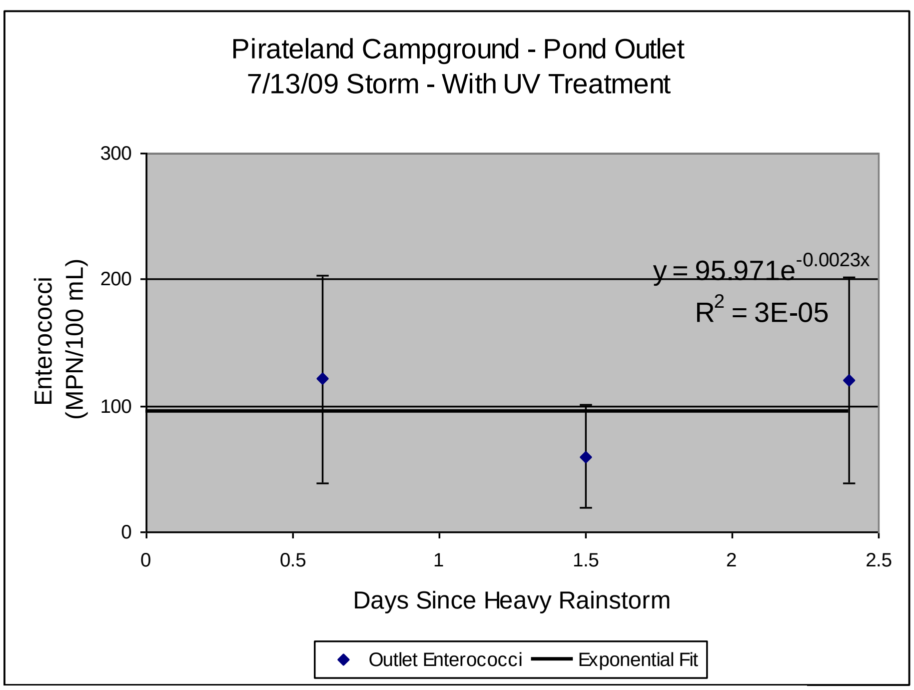

Figure 8 – UV Treatment during 0.6 inch rain

Figure 8 indicates exponential fit of enterococci bacteria concentrations at outlet of Pirateland Campground Pond after July 2009 (0.6 inch) rainstorm. Error bars indicate approximate 95% confidence limits of data points.

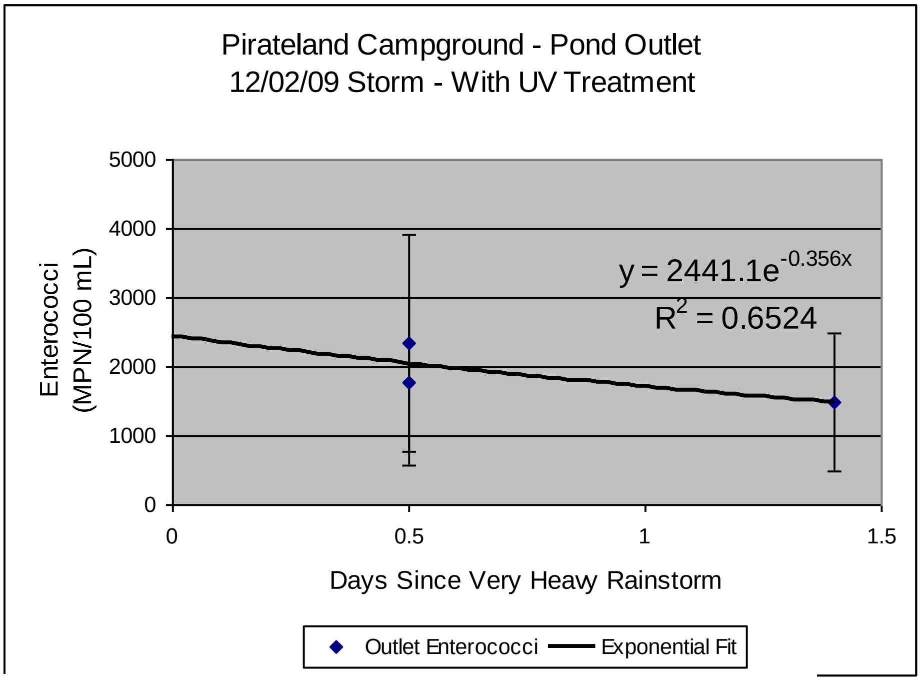

Figure 9 – UV Treatment during 2.6 inch rain

Figure 9 indicates exponential fit of enterococci bacteria concentrations at outlet of Pirateland Campground Pond after December 2009 (2.6 inch) rainstorm. Error bars indicate approximate 95% confidence limits of data points.

Measurement results from samples collected on the same days in both campgrounds and from the swash between the campgrounds when the UV system was and was not operating were compared to further evaluate the effectiveness of the UV system.

CONCLUSION AND RECOMMENDATIONS

The following general conclusions are based on field measurements, laboratory data, and observations obtained during the UV testing of the Blue Heron Pond located in the Pirateland Campground:

1. Tests of the UV treatment system indicate that UV light is effective for disinfection of pond water. The overall results show that enterococci concentrations for the treated pond are decreased by close to an order of magnitude, as compared to the untreated pond.
2. Following rainfall events, the half-removal times for fecal coliform in the pond were as follows:
    - **a.** For rain events of 0.5-1.5 inch in depth the half removal was about 0.9 days
    - **b.** For rain events of greater than 2 inches in depth, the decrease was insignificant
3. For storm events that are more common and frequent, those less considerably less than 1.5 inches, the treatment is highly effective in reducing the enterococci levels to below or slightly above the SCDHEC swimming advisory criteria of 104 MPN/100 mg/L.

4. With the majority of pollutant runoff occurring in the more frequent less intensity storm events, one can conclude the treatment strategy can target the majority of the pollutant runoff.
5. Measured turbidity at the pond outlet was on average less than 13 NTU, with a range of 5.5 to 32. High turbidity corresponded to high rainfall events, which may have influenced the performance of the UV treatment.
6. Variability in watershed runoff as a result of time between rain events, time of year, and human and wildlife activity, can present considerable variability in concentration levels entering and leaving the treated pond.
7. The configuration of the pond and the location of the inlet, outlet, as well as the secondary entrance (found after construction) can influence the pond's ability to fully treat the pond water prior to a storm event.
8. Capital and power costs for the UV Facility were approximately:
    - **a.** Engineering - $75,000
    - **b.** Equipment and Construction - $300,000
    - **c.** Power consumption - $700/month (for 24 hour/day operation)

The results of this study and the conclusions presented above support the following the recommendations:

1. The use of the Blue Heron Pond UV Facility should be continued as a component to Horry County's strategy to manage water quality in its receiving streams.
2. The daily maintenance of the unit should be continued to document UV intensity, flow, debris and growth in the intake structures, and bulb performance.
3. Additional testing should be considered to understand the influence on pond performance through variation of unit operations (i.e. less than 24 hours/day of unit operation, alternating days of full power operation, etc), which can assist in optimizing performance and minimizing power consumption.
4. Continued sampling during alternate operations to continue to build data to support a long term operational strategy.
5. Identification of a site that contains a smaller watershed, with controlled inflow and outflow, diverse land use, and proximity to existing sampling locations, to allow the County to understand the technology's ability to be scaled down (or up) for additional locations.