FINAL REPORT FOR TWO OCRM STUDIES: STORMWATER POND BASELINE AND EFFICIENCY

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PROJECT SUMMARIES

- **Stormwater Pond Baseline Study Findings**
  - Low nutrients, high fecal coliform bacteria possible and related to rainfall events, high chlorophyll *a* levels were common and algal blooms were recorded
  - Ponds were not tidally influenced (98% of ponds had salinity < 2 ppt)
  - Ponds are a potential fecal coliform bacteria source
  - Eutrophication of ponds in SC's coastal zone is a concern

- **Stormwater Pond Efficiency Study Findings**
  - Ponds are filling in with sediment over time
  - A single pond was less effective in runoff pollutant removal than a terminal pond in a five pond system
  - Pollutant removal efficiencies varied between the two ponds studied and within the sampled rain events
  - Water was released from the single pond's outlet faster than the terminal pond
  - Runoff can enter receiving water faster than the modeled permitted conditions

- **Management Implications**
  - Baseline and efficiency studies indicate that stormwater ponds have eutrophic symptoms and runoff can enter receiving water faster than the modeled permitted conditions and the cumulative effect to the natural waterbodies is unknown
  - A focal shift from water quantity to water quality through parameters such as nutrients, sediment removal, bacteria, and/or chlorophyll *a* could help protect waterways
  - Regulating smaller, more frequent storm events could address the cumulative impact of runoff since the design events rarely occur

INTRODUCTION

During the past two decades, southeastern coastal counties have experienced rapid growth, much of which has occurred in the form of sprawling residential development that consumed land at a rate nearly six times higher than population growth (Allen and Lu 2003). Because of the high levels of impervious cover associated with this type of development (roofs, parking lots, roads, etc.), non-point source pollution is one of the most significant threats to coastal waters and habitats in the region. Although a variety of reduction and treatment practices have been developed, the use of stormwater ponds is the most common practice employed to address non-point source pollution in the coastal zone. In fact, recent estimates place the number of stormwater ponds in coastal SC at over 8,000, making these waterbodies an increasingly significant feature of the coastal landscape. Stormwater ponds are also used to provide recreation such as boating and fishing, enhance aesthetics, increase residential property value, and provide habitat for wildlife. Yet relatively little is known about the collective role of these "best management practices" (BMPs) in addressing non-point source pollution.

Stormwater ponds, including detention ponds (water gradually released through an outlet structure to adjacent surface waters) and retention ponds (water gradually released through infiltration into the soils and evaporation), were originally intended to manage localized flooding. Over the past decade, stormwater ponds have been increasingly expected to (or in some cases required to) address water quality concerns for receiving waters, including the removal of pollutants (e.g., nutrients, bacteria) through physical, chemical, and biological processes in the water column. To protect water quality during construction and development, SCDHEC-OCRM requires projects within ½ mile of a receiving waterbody or that disturb ≥ one acre(s) to obtain a stormwater management permit. These permits require 80% sediment removal during construction, and that post-development runoff rates are less than or equal to pre-development rates for a 2 and 10-year storm event. Regulations also require that the first 1-inch of a rainfall event, which is presumed to produce the highest concentration of pollution in surface runoff, is detained for 24 hours to allow sediment and associated pollutants to settle.

While stormwater ponds are valuable in reducing flooding, there is some evidence that they may not be providing all of the assumed water quality benefits, and could even have unintended negative impacts on environmental quality and/or human health. Recent information indicate that ponds may act as "incubators" for harmful algal blooms (HABs) (Lewitus et al. 2003) and/or fecal coliform bacteria. Also, if not properly maintained, ponds can accumulate sediment and debris and have slope and/or outlet failures, resulting in high sediment and pollutant loadings to receiving waters. Structural designs and other factors such as age, location, and connections to other ponds are likely to influence pond function and performance; however, these relationships are not well understood. Pollutant removal efficiency findings in other studies have varied due to differences in pond size, volume, shape, residence time and ratio of pond area to catchment area (Pettersson et al. 1998; Walker 1998; Some et al. 2000), and local studies are limited. Therefore, there was a need to assess the water quality and pollutant removal efficiencies of stormwater ponds in South Carolina coastal areas to better understand their role in treating stormwater runoff.

In 2006, SCDHEC-OCRM conducted a stormwater pond baseline water quality study, and a pollutant removal efficiency study. The baseline water quality study sampled 112 ponds that were permitted ~5 years ago in SC's eight coastal counties (Figure 1) to determine the following: (1) What are the water quality conditions (i.e., dissolved oxygen, salinity, nutrient, fecal coliform bacteria, chlorophyll a, turbidity, and suspended solids) in stormwater ponds?; (2) Is eutrophication of ponds a concern?; (3) Are ponds a potential source of fecal coliform bacteria contamination?; and (4) Are ponds tidally influenced?

The goal of the pollutant removal efficiency study was to evaluate the performance of two wet detention ponds on Daniel Island, SC (Figure 2). One pond was the fifth and terminal pond in a linked series of ponds (termed MRP), while the second pond was a single pond system (termed SRP). Pollutant removal efficiencies and water budgets were developed for each of the ponds. The objectives of this study were to: (1) perform a bathymetry study of two ponds; (2) determine the pollutant removal efficiencies of two ponds; and (3) determine if the two ponds are meeting the SC regulations for pre- and post-development runoff rates.

METHODS

Baseline Water Quality Study

All water quality samples were collected near the stormwater pond outfall structure at a depth of 0.3 m. Physical parameters were measured using a YSI 85 for temperature (T), dissolved oxygen (DO), salinity, and specific conductivity. Water samples (whole fraction) were analyzed for total nitrogen (TN), nitrate plus nitrite (NO_3^- plus NO_2^-), ammonia-nitrogen (NH_3-N), total phosphorus (TP), orthophosphorus (OP), fecal coliform bacteria, chlorophyll *a,* phaeopigment, turbidity, and total suspended solids (TSS) (SCDHEC Quality Assurance Project Plan, 2006). When pond conditions indicated an algal bloom (visual observation or DO > 100% saturation) or hypereutrophication (chlorophyll *a* >60 µg L^{-1}, according to Bricker et al. 2003), live algal screenings or preserved screenings for algal composition including HABs was conducted. Site features were also recorded, such as amount of vegetation surrounding and within the pond and if aerators were present. In addition, site rainfall prior to sampling was gathered using the nearest weather station (CLIMOD, Retrieved 2007). Ponds were grouped into land use categories for analysis (i.e., residential, commercial, golf course, and industrial).

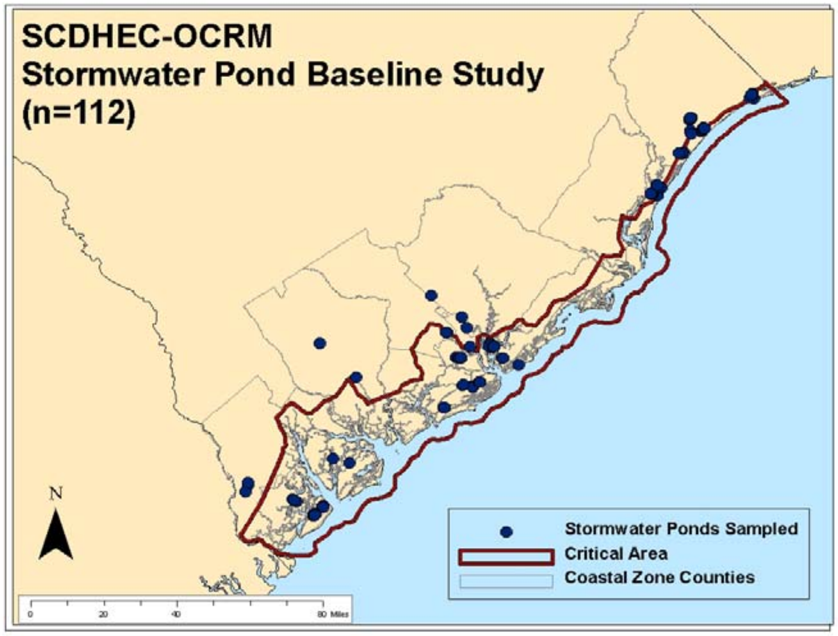


Figure 1 Stormwater pond water quality baseline study sites in SC's coastal zone.

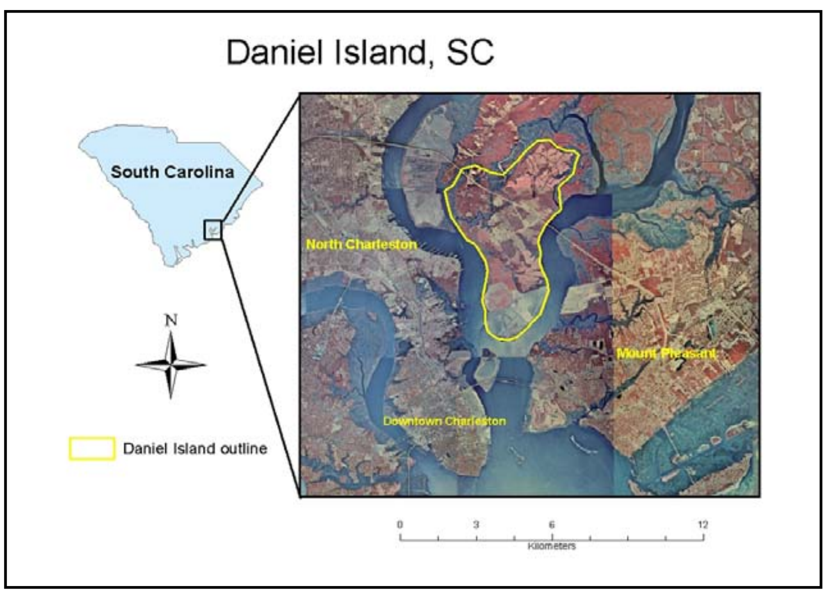


Figure 2 Stormwater pond pollutant removal efficiency study location in SC's coastal zone.

Pollutant Removal Efficiency Study

Bathymetry and pond volume were measured through surveys using a Garmin ® GPSMAP 135 Sounder with Garmin's ® GBR 23 beacon receiver to collect location and depth coordinates. This data was integrated into a Geographical Information System (GIS) to determine pond bathymetry and volume. Physical water quality (T, DO, conductivity, depth, and pH) was continuously measured near the bottom of the pond. Water samples in each pond were collected at a depth of 0.3 m prior to each rain event (pre) and after each rain event at approximately 24 and 48 hours (post-24 and post-48). These samples were analyzed for fecal coliform bacteria, TSS, TN, NO_3^- plus NO_2^-, NH_3-N, dissolved TN, dissolved NO_3^- plus NO_2^-, dissolved NH_3-N, TP, total dissolved phosphorus (TDP), and OP. Teledyne ISCO 6712 Portable Auto Samplers (ISCO) equipped with an Area Velocity Flow Module and rain gauge were used to collect rainfall data, hydrographic data, and flow-weighted composite samples during rain events. During the rain events, flow-weighted composite samples (i.e., more frequent sampling occurred during periods of greater flow) were collected. These composite samples were analyzed for the same parameters mentioned above. Stormwater runoff, water budgets, event loadings, and pollutant removal efficiencies for each rain event were then determined (Messersmith, 2007).

RESULTS

Baseline Water Quality Study

Stormwater ponds in SC's coastal zone vary greatly in size, shape, surrounding land uses, and inflow and outfall structures. The stormwater pond water quality baseline study found that (1) most had very low surface salinity levels (<1 ppt), (2) about 20% had low DO (< 4 mg L^{-1}), (3) 32% had high chlorophyll *a* levels (>40 µg L^{-1}), (4) algal blooms including HABs were common, and (5) the highest fecal coliform bacteria (i.e., an indicator of fecal matter bacteria) occurred after rain events, with ~23% of the ponds having >400 colony forming units 100 mL^{-1}. High fecal coliform bacteria concentrations were found more often in residential and commercial areas than in industrial and golf course areas ($p \leq 0.05$, $X^2=17.6$, df=9). Figures 3 and 4 show the stormwater pond chlorophyll *a* and fecal coliform bacteria results. In general, nutrient concentrations were low (TN < 1 mg L^{-1} and TP < 0.09 mg L^{-1}); however, high chlorophyll *a* levels indicate nutrients were entering ponds. The National Eutrophication Assessment considers chlorophyll *a* ≥ 60 µg L^{-1} to be hypereutrophic, while levels ≥ 20 µg L^{-1} and < 60 µg L^{-1} are considered high (Bricker et al., 1999). Fixed lugol water samples with chlorophyll *a* ≥ 60 µg L^{-1} which is considered hypereutrophic while levels ≥ 20 µg L^{-1} and < 60 µg L^{-1} are considered high by the National Eutrophication Assessment (Bricker et al., 1999), were processed for algal composition and 80% contained algal blooms with one to many species in bloom proportion. In fact, all but one bloom sample had ≥ 1 algal species documented to be a suspected or known toxin producers (i.e. harmful) (Brock, 2007). Algal blooms species were almost exclusively from the class Cyanophceae and the three most frequent genera were *Aphanizomenon*, *Microcystis*, and *Oscillatoria*. Since algae composition can be early indicator of water quality, increased nutrient input into stormwater ponds can promote algal growth, including harmful algae, and increase the morning respiration resulting in fish kills. Using GIS analysis, 72% of ponds were within 0.5 miles of a receiving water. Therefore, eutrophication of SC stormwater ponds is a management concern.

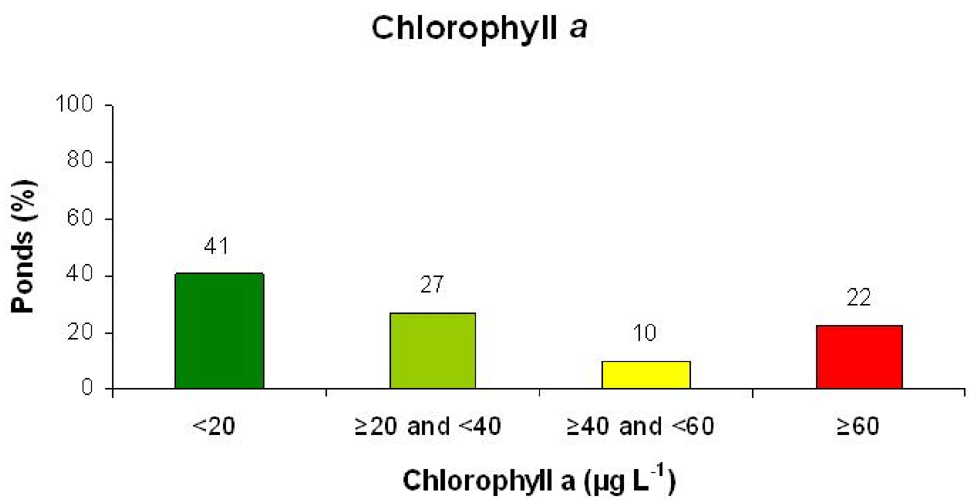


Figure 3 Stormwater pond baseline study chlorophyll a concentrations.

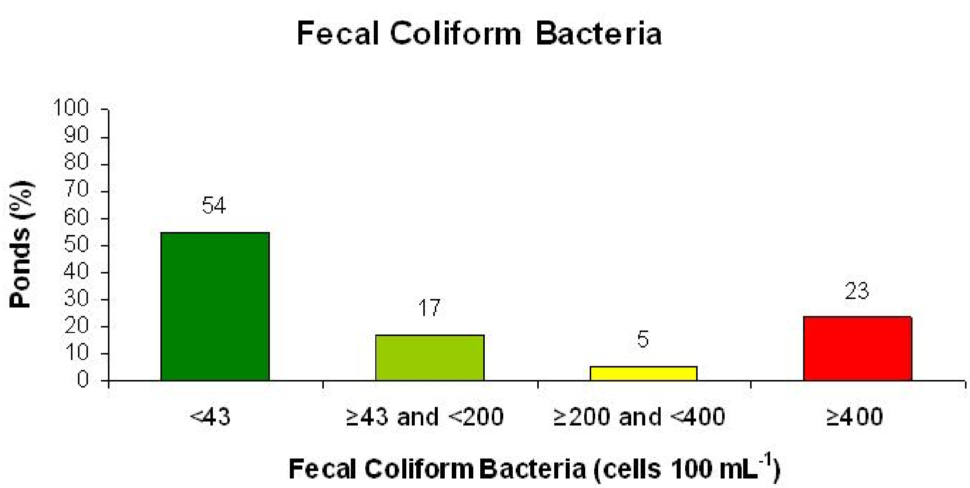
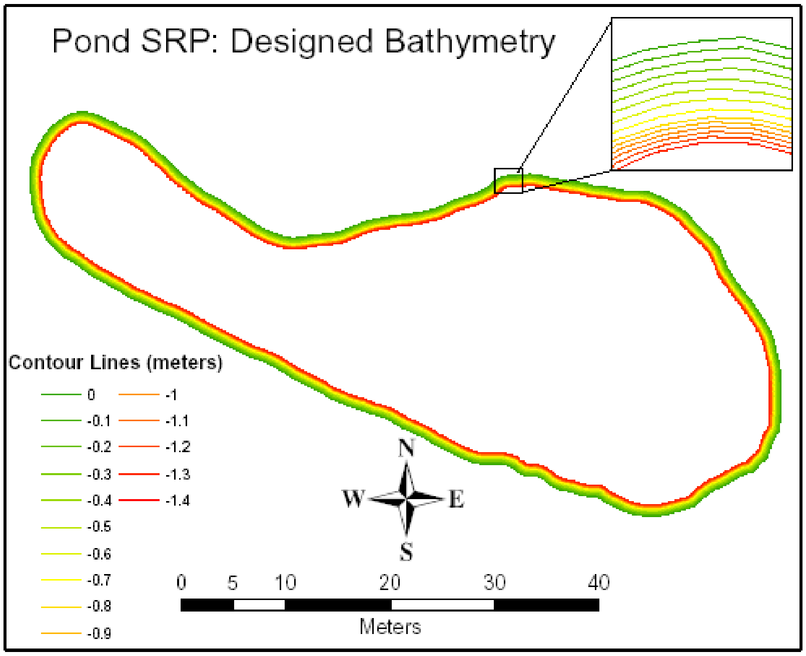


Figure 4 Stormwater pond baseline study fecal coliform bacteria concentrations.

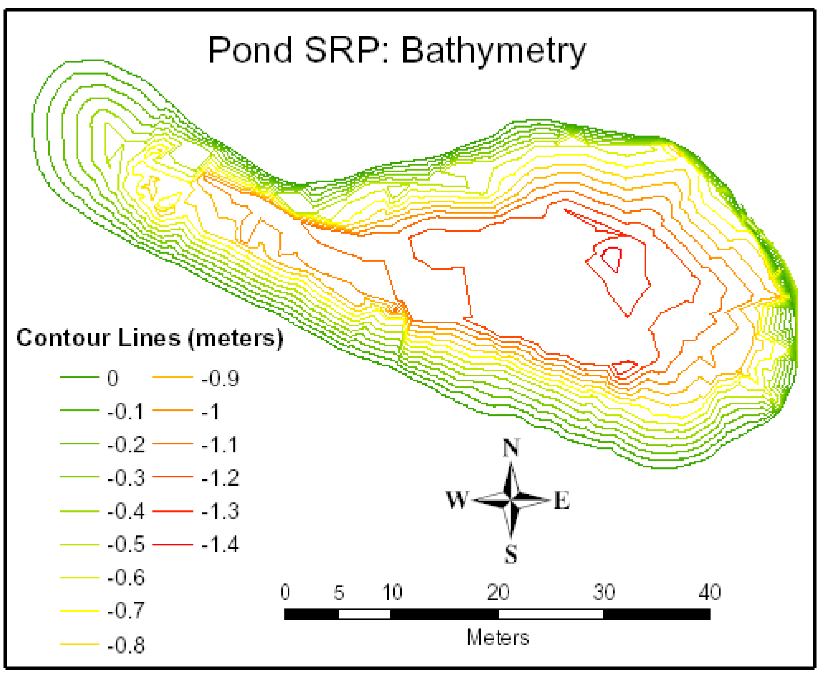
Pollutant Removal Efficiency Study

According to bathymetry measurements, both ponds have filled in over time, especially around the inlet pipes and pond edges (Figure 5). This reduces the water volume and residence time of the pond and its ability to detain stormwater runoff, which could result in higher loadings of pollutants entering receiving waters. The linked pond lost 15.1 % of its storage capacity, while the single pond lost 36 % of its storage capacity. Pollutant removal efficiencies varied by rain event and pond site, with nutrients, fecal coliform bacteria, and TSS ranging from –208 to 95%, –477 to 99%, and –79 to 91%, respectively. Removal of the total pollutant load from all rain events captured within each pond provided the most appropriate way to characterize removal efficiency (Figure 6). In general, the single pond removed pollutants less effectively, had higher efficiency variability, and discharged water after storm events much faster than the pond in a multiple series system. Most rain events in the study were much smaller than the modeled storm events (4.5 and 6 inches over 24 hours) so a direct comparison to pre and post development runoff rates could not be made. Both ponds released water over a 24-hour period, yet the hydrographs reveal that the single pond released the majority of its water much faster than the multiple pond system (Messersmith, 2007).

Both studies indicate that stormwater pond discharges may be a concern for receiving waters. However, the history of pond maintenance by landowners was usually unknown, as was the role of pond size, depth, and other characteristics that could relate to pond performance. Future analyses will be focused to try and elucidate this as well as starting to develop a classification system to identify stormwater pond types.



(A)



(B)

Figure 5 Example of designed bathymetry (A) and current bathymetry (B) in the single pond **(Messersmith, 2007).**

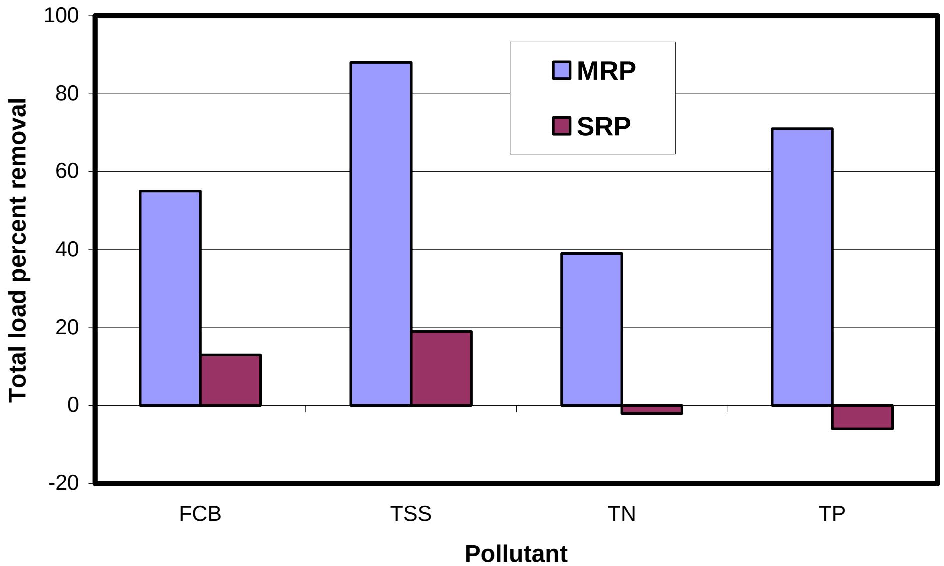


Figure 6 Total pollutant removal efficiencies of MRP and SRP **(Messersmith, 2007).**

MANAGEMENT IMPLICATIONS

The results of these studies indicate a number of important implications for stormwater engineers and managers, as well as future research projects including: (1) water quality issues related to stormwater management; (2) the event variability of pollutant removal; and (3) the importance of watershed-scale management for sustainable development practices. Stormwater ponds are increasing along with land development in SC's coastal zone and the potential cumulative impacts of this stormwater BMP should be identified. The baseline study indicates that water quality in the ponds is diminished with respect to algae and fecal coliform bacteria, and the efficiency study determined that a pond in series appears to function more effectively than a single pond. A stormwater management water quality focus can help protect our economically and ecologically viable estuaries. This can be accomplished through models that focus on nutrient and sediment removal instead of water volume alone, using runoff calculations on the less intense, more frequently occurring rain events, and encouraging the use of alternative stormwater controls such as reduced impervious surfaces, swales, rain gardens, and/or constructed wetlands in stormwater plans. In addition, little information is available regarding sediment contaminants (pesticides, organics, heavy metals, or other pollutants) that can accumulate over time and may prove to be a risk to humans and wildlife. This year, a third study will determine if pond sediments are contaminated, and what, if any, health risks exist. SCDHEC-OCRM's stormwater pond management will be strengthened by the results of these studies.

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