East Carolina University

Onsite Wastewater System Nitrogen Treatment Efficiency in Response to Groundwater Fluctuations

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Abstract

Onsite wastewater systems (OWS) are a common method of wastewater treatment in coastal regions across the world. OWS rely on aerobic soil beneath drainfield trenches for pollutant attenuation and transformations. Sea level rise and climate change are projected to increase groundwater table elevations in many coastal areas. The vadose zone thickness beneath existing OWS drainfield trenches may be reduced as a result, potentially influencing pollutant treatment. The objective of this study was to determine if the nitrogen treatment efficiency of an OWS serving a school in the Coastal Plain of North Carolina was influenced by water table fluctuations. Monitoring wells (6) were installed between the drainfield trenches of a large OWS and in one background location. Groundwater readings including depth to water, pH, temperature, specific conductance, and dissolved oxygen were recorded 8 times over a 15 month period during periods of relatively "low" and "high" water tables. Septic tank effluent and groundwater from the monitoring wells were collected for analyses of total dissolved nitrogen (TDN) during each field visit for comparison and to determine if the nitrogen treatment efficiency was influenced by the water table elevation. The TDN treatment efficiency of the OWS was inversely correlated to water table elevation (r = -0.754; p = 0.031). Significant differences in groundwater TDN concentrations were observed across the drainfield suggesting dilution was more prevalent on the up-gradient section of the dispersal field. Results suggest that OWS should be installed with the maximum depth to groundwater and oriented (long trenches installed perpendicular to groundwater flow direction) to maximize wastewater mixing with groundwater beneath the drainfield to accommodate for expected future increases in groundwater elevations

Introduction

- Wastewater contains elevated concentrations of nitrogen (25 to 100 mg/L) and if onsite wastewater treatment systems (OWS) are not efficient at reducing nitrogen concentrations then groundwater and surface waters adjacent to the systems may become enriched
- Excess nitrogen in surface waters can lead to algal blooms (some toxic), eutrophication, fish kills, water use impairment, loss of ecosystem services and loss of revenue from less tourism, fishing, and recreation
- Major water resources in North Carolina including the Neuse River, Tar Pamlico River, Falls Lake and Jordan Lake are nutrient sensitive and nutrient management strategies have been developed to reduce nutrient loadings to these water resources
- Nitrate (NO_3^--N) is the most common species of nitrogen found in groundwater beneath well aerated OWS, and NO_3^--N is very mobile in soil and groundwater
- Excess nitrogen in groundwater can lead to methemoglobinemia, and other public health concerns
- The maximum contaminant level for NO_3^--N is set at 10 mg/L
- Specific conductivity, pH, dissolved oxygen, and other environmental readings are important for characterizing and delineating wastewater plumes in groundwater and understanding nitrogen transformations
- The objective of this study was to determine if the nitrogen treatment efficiency of an OWS serving a school in the Coastal Plain of North Carolina was influenced by water table fluctuations

Materials and Methods

Figure 1. Monitoring wells were installed between the drainfield trenches of the onsite wastewater system. Soil profiles were described and soil samples were collected for particle size distribution analyses. Wells were finished below grade and encased in protective valve boxes.

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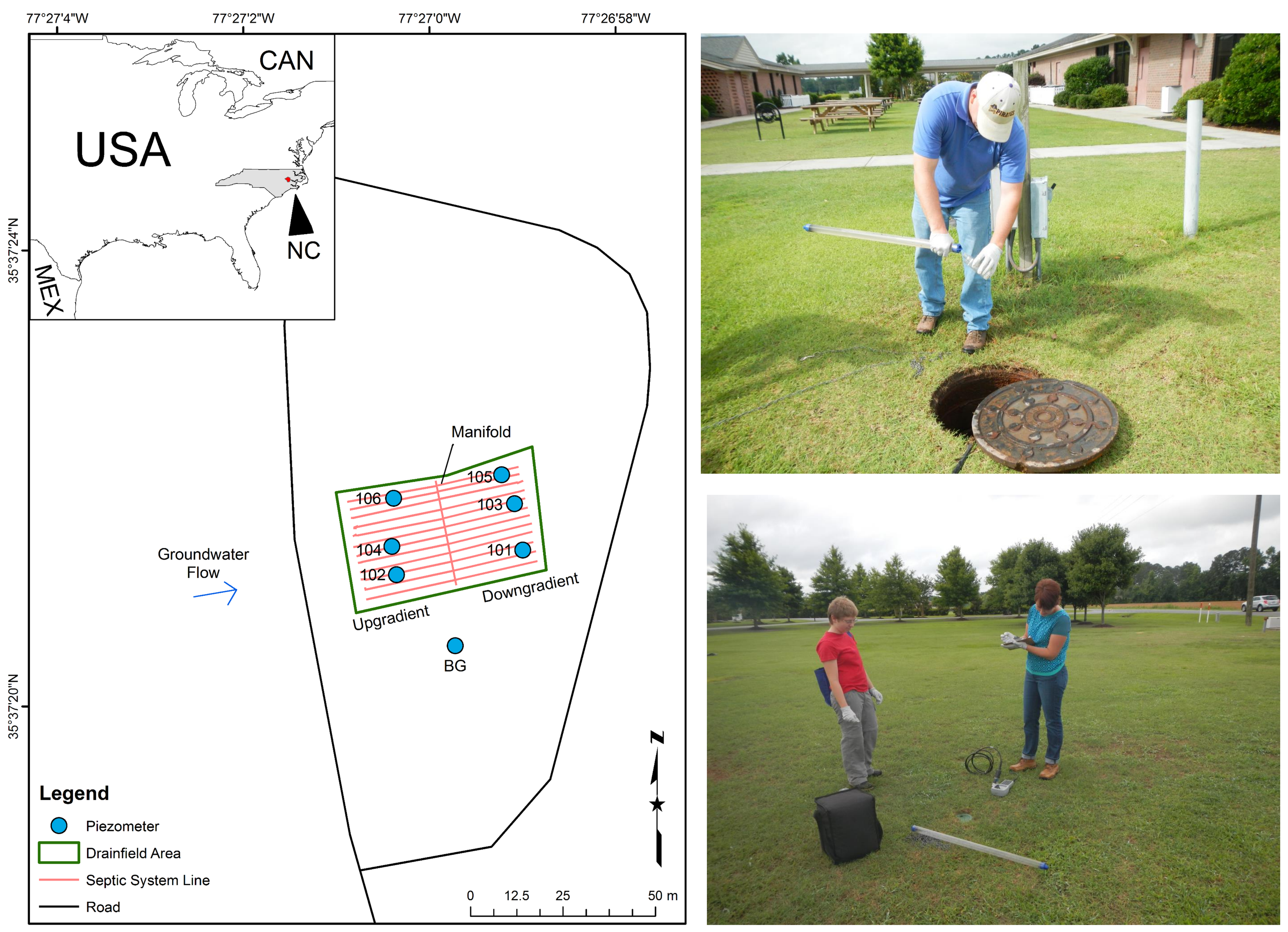

Figure 2. Water samples were collected from 6 modified wells (piezometers) installed between the drainfield trenches, one background piezometer (BG), and from the septic tank for nitrogen analyses. Groundwater flow direction was predominantly northeast. Three piezometers were installed on the upgradient and downgradient sides of the pressure manifold. Samples were collected using disposable bailers during 8 different events. Environmental readings including depth to groundwater, pH, specific conductance, temperature, and dissolved oxygen were measured in the field during sample collection.

- Nitrogen concentrations in septic tank effluent were compared to concentrations in groundwater beneath the onsite wastewater system to determine treatment efficiencies (concentration reduction)
- Nitrogen concentrations in groundwater beneath the drainfield on the upgradient and downgradient sides were compared to determine if differences in dilution rates may influence concentrations
- The physical and chemical properties of water including pH, specific conductance and dissolved oxygen were compared for septic tank effluent, groundwater beneath the drainfield and background groundwater to determine if differences were statistically significant and if septic effluent was influencing groundwater characteristics
- Nitrogen treatment efficiency and relative groundwater elevations were calculated for each sampling event and correlation analyses were performed to determine if there were statistically significant relationships between nitrogen treatment and water table elevation

Results and Discussion

Table 1. Physical and chemical characteristics of water including mean and (standard deviation) of pH, dissolved oxygen (DO), temperature, specific conductance (SC), total dissolved nitrogen (TDN), and percentage of nitrogen that was NO_3, NH_4, and dissolved organic nitrogen (DON). Groundwater characteristics beneath the drainfield trenches on the upgradient (UG) and downgradient (DG) side of the pressure manifold, and all drainfield samples (DF) were pooled. Septic tank effluent had the highest mean TDN, pH, SC, and temperature, and lowest mean DO. Groundwater beneath the drainfield had higher TDN and SC relative to background groundwater and lowest pH.

Sample Location	pH	DO (mg/L)	SC (µS/cm)	Temperature (°C)	TDN (mg/L)	% NO3	% NH4	% DON
101	4.1 (0.7)	3.8 (2.2)	794 (293)	20.0 (5.8)	59.3 (30.0)	91	8	1
102	4.4 (0.7)	3.1 (2.7)	615 (270)	19.8 (5.6)	43.1 (17.0)	81	18	1
103	4.3 (0.4)	4.5 (3.4)	369 (266)	19.7 (6.2)	24.9 (19.1)	95	2	3
104	4.4 (0.5)	3.2 (2.4)	313 (183)	19.6 (5.9)	19.4 (12.9)	87	10	3
105	3.7 (0.4)	3.2 (2.3)	890 (311)	19.5 (6.1)	69.1 (28.4)	95	3	2
106	4.3 (0.5)	3.1 (2.0)	374 (129)	19.9 (5.8)	25.1 (12.2)	92	5	3
Back Ground	5.6 (0.7)	3.2 (1.9)	106 (63)	20.6 (5.8)	1.5 (0.9)	53	6	41
Septic Tank	6.4 (0.6)	1.9 (1.0)	1288 (267)	22.7 (6.8)	91.1 (28.8)	1	90	9
Drainfield	4.2 (0.5)	3.5 (2.4)	592 (426)	20.3 (5.6)	41.6 (12.7)	90	8	2
Drainfield-UG	4.3 (0.5)	3.2 (2.4)	434 (235)	20.1 (5.4)	29.2 (17.0)	87	11	2
Drainfield -DG	4.0 (0.5)	3.6 (2.5)	668 (364)	20.5 (5.2)	51.5 (31.6)	94	4	2

Results and Discussion

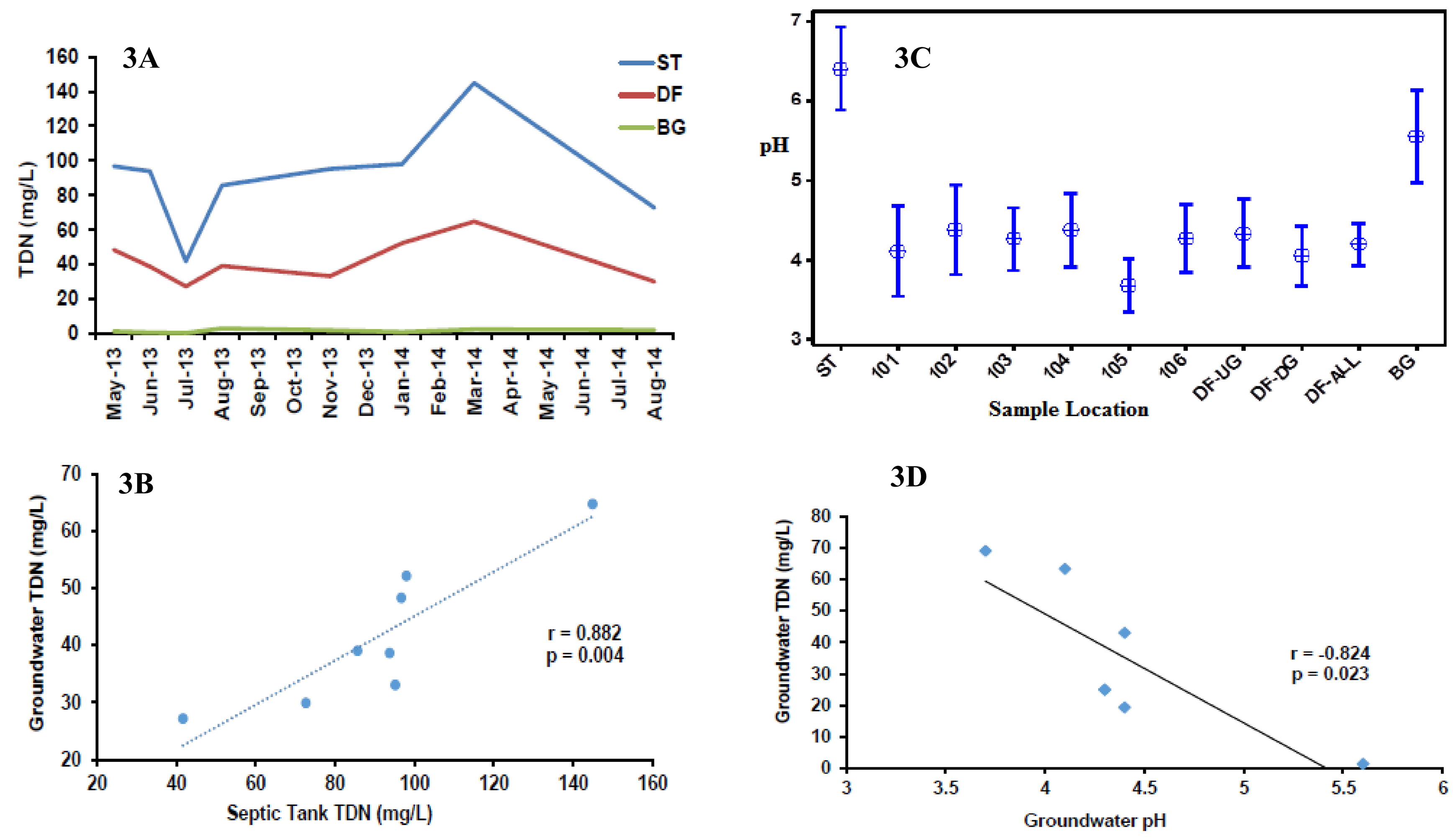

Figure 3. The TDN concentrations in groundwater beneath the drainfield (DF) were always elevated relative to background groundwater (BG) and lower than septic tank effluent (ST) concentrations (3A). There was a statistically significant correlation between TDN concentrations in septic tank effluent and groundwater beneath the DF (3B). The pH of groundwater beneath the DF was significantly lower relative to background groundwater and septic tank effluent (3C), possibly because of the release of H^+ during the oxidation of NH_4^+ to NO_3^- (nitrification). Septic effluent was mostly NH_4^+, while groundwater beneath the DF was mostly NO_3^- (Table 1). There was a statistically significant inverse correlation between groundwater TDN concentrations and groundwater pH beneath the DF (3D).

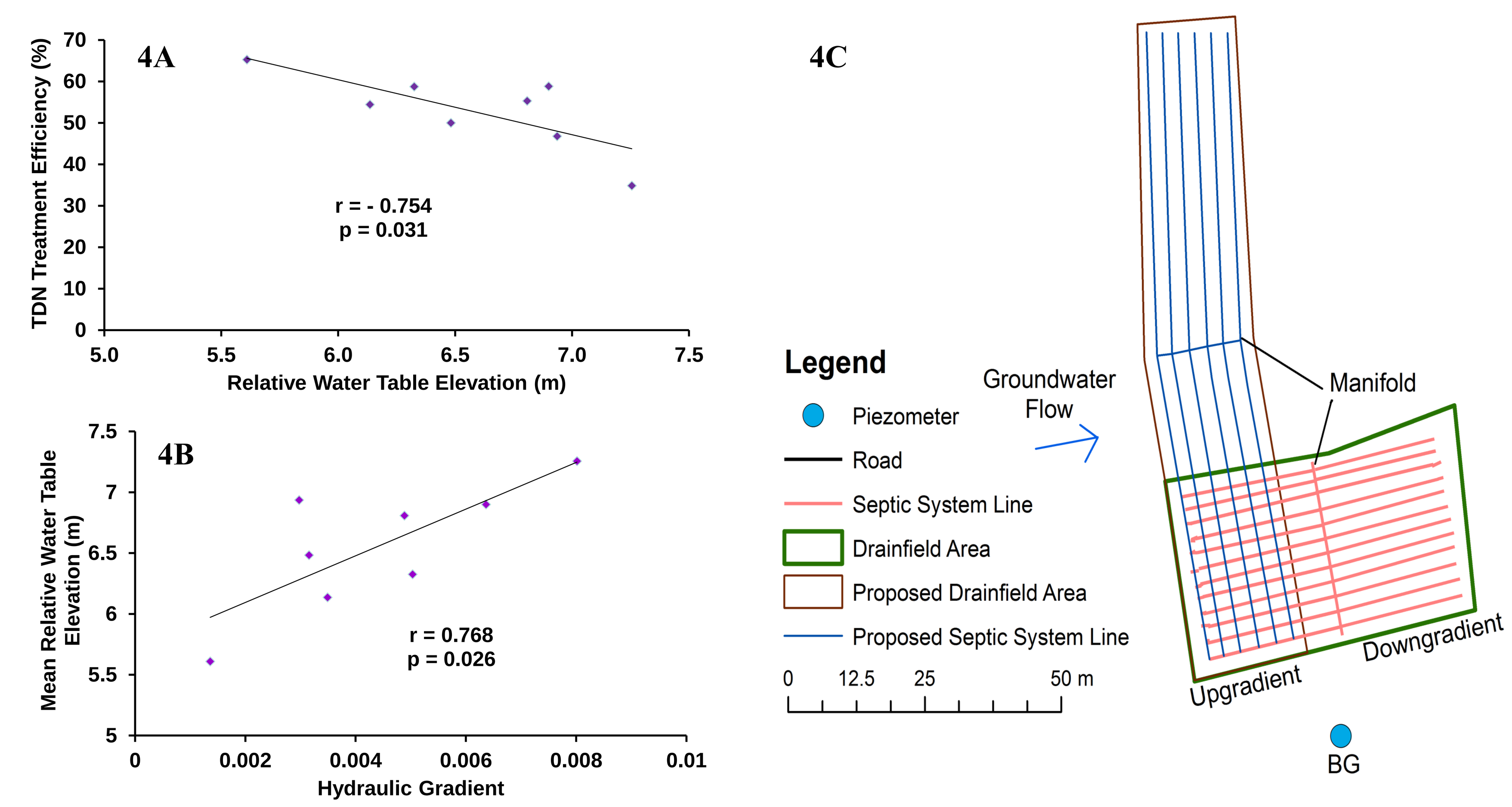

Figure 4. The TDN treatment efficiency was inversely correlated with relative mean water table elevation, so when groundwater levels were high, treatment efficiency was relatively low (4A). The hydraulic gradient was correlated with the mean relative water table elevation, so when groundwater elevations were high, the hydraulic gradient (and groundwater flow away from the system) increased (4B). Nitrogen concentrations and specific conductance in groundwater beneath the drainfield on the down-gradient side of the manifold were greater relative to the up-gradient side, suggesting less dilution on the downgradient side (Table 1). To increase dilution and thus lower nitrogen concentrations in groundwater, an OWS designed with longer drainfield trenches oriented perpendicular to groundwater flow is suggested (4C).

Conclusions

The TDN treatment efficiency of the OWS was influenced by the water table elevation and separation distance to groundwater. Seal level rise and increased rainfall due to climate change may cause increases in water table elevations for some coastal areas and thus influence OWS treatment efficiency of pre-existing systems. Increasing the required separation distance from OWS to groundwater in coastal areas, and installing drainfield trenches that are long and perpendicular to groundwater flow are recommended to improve the treatment efficiency of OWS. More research regarding retrofit best management practices for reducing pollutant transport from OWS is suggested.

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