CONSTRUCTED WETLANDS

Development Guide

January 2026

CONTENTS

CITY OF WILMINGTON STORMWATER

HEAL OUR WATERWAYS

NC STATE UNIVERSITY Bio&Ag ENGINEERING

INTRODUCTION

Wet retention ponds, a traditional form of “gray” stormwater infrastructure, have historically been the most common treatment method in developments. Recently, stormwater research has shifted toward exploring alternative ways to enhance pollution treatment within Stormwater Control Measures (SCMs), emphasizing water quality, habitat, and community improvements.

This guide introduces constructed stormwater wetlands as an alternative to wet retention ponds, given their comparable space needs, design, and cost. Wetlands incorporate more natural processes to improve treatment potential, add wildlife corridors, and provide an amenity space for communities to visit and enjoy.

The goal of this guide is to provide real-world examples, tips, and justification for using constructed wetlands for stormwater treatment.

This guide contains examples and supplemental information, and is NOT a replacement for NCDEQ’s Minimum Design Criteria (MDC) for Constructed Wetlands. For permitting purposes, please refer to the NCDEQ Stormwater Design Manual, C-4, for the full stormwater wetland MDCs.

TROUBLE WITH PONDS

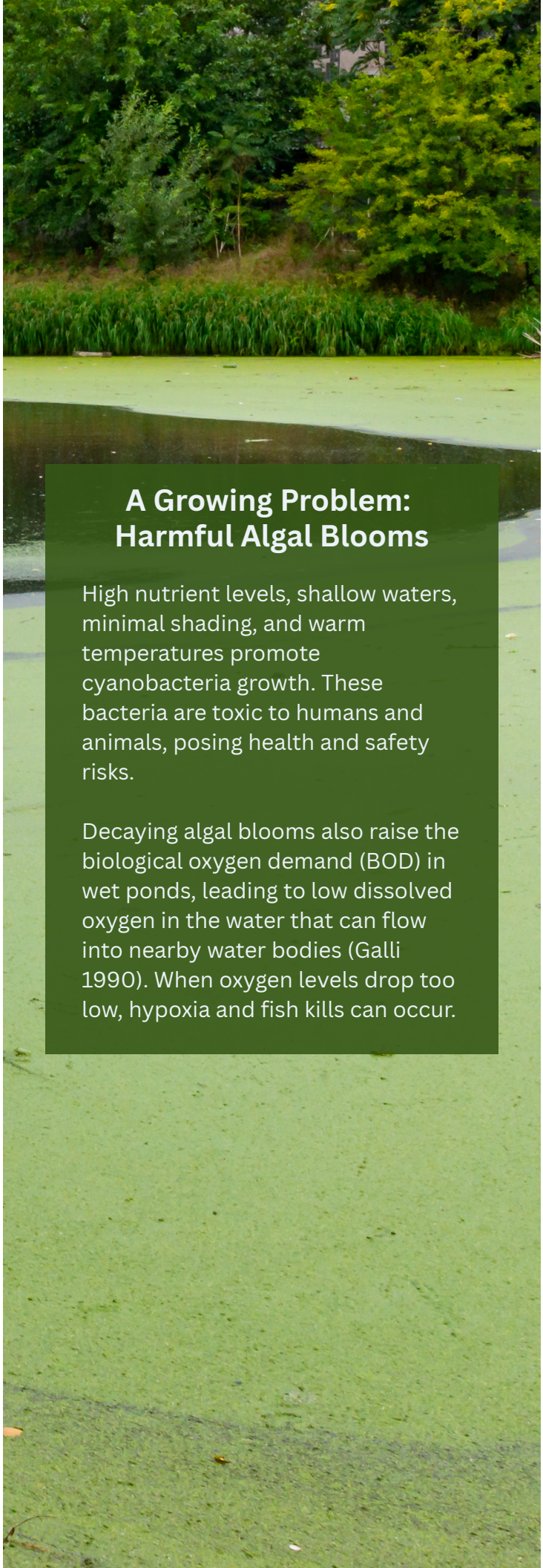
Retention ponds are the most commonly used SCM due to their simplicity and straightforward costs. However, ongoing research is investigating their efficacy in regards to a few growing concerns:

- **Temperature**: Direct sunlight on wet ponds can increase the water temperature, which can harm cold-water animals in warm areas like Wilmington.

- **Habitat Loss & Water Flow Changes**: Standard stormwater ponds often don't handle all the water or pollutants properly, so some places prefer other methods unless ponds are the only option. They can also disrupt natural water flow, affecting streams and habitats.

- **Pollution Treatment Limits**: Retention ponds try to clean water by settling out dirt and pollutants, but they often don't remove all of them, especially tiny sediments and bacteria from animals like geese. Some pollutants, like chemicals and metals, can remain in ponds and may be washed back into the environment during heavy rains.

To be clear, retention ponds are still an accepted SCM for stormwater management, but alternative nature-based strategies are available that can offer additional co-benefits in regards to the concerns above.



A Growing Problem: Harmful Algal Blooms

High nutrient levels, shallow waters, minimal shading, and warm temperatures promote cyanobacteria growth. These bacteria are toxic to humans and animals, posing health and safety risks.

Decaying algal blooms also raise the biological oxygen demand (BOD) in wet ponds, leading to low dissolved oxygen in the water that can flow into nearby water bodies (Galli 1990). When oxygen levels drop too low, hypoxia and fish kills can occur.

ALTERNATIVE TO PONDS: CONSTRUCTED WETLANDS

One such nature-based alternative is a constructed stormwater wetland, which is a man-made ecosystem designed to manage and treat stormwater runoff. They work like natural wetlands by using a combination of water, soil, and plants to filter and clean stormwater before it reaches local waterways. Unlike wet ponds, constructed wetlands provide natural filtration that improves water quality and supports diverse plants and wildlife.

Enhanced vegetation in wetlands improves pollution filtration by absorbing and treating contaminants, not just relying on sedimentation. A local study suggests designing stormwater systems with substantial vegetation, especially rooted emergent plants, to promote pollutant uptake, increase aeration, and boost organic matter in sediments (Mallin et al. 2002). Extensive aquatic vegetation also prevents algal blooms by absorbing nutrients and shading, lowering water temperature (Richard and Small, 1984).

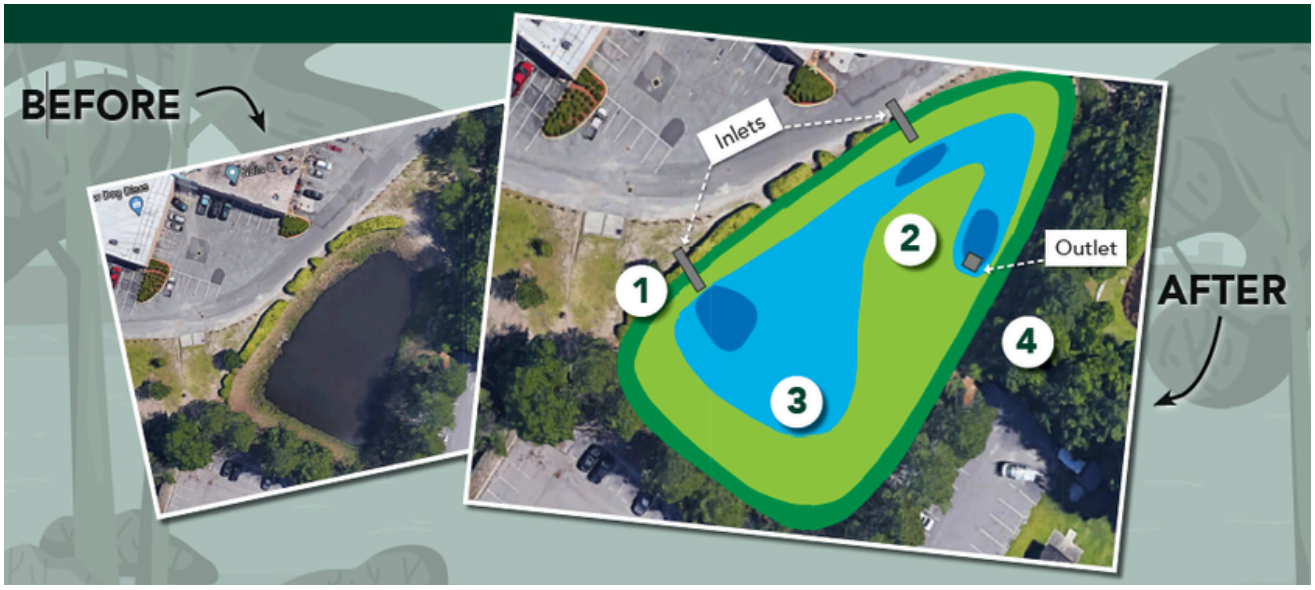
Passing stormwater through wetlands as a final upstream treatment is also recommended to reduce pollutants (Mallin et al. 2002).

Constructed stormwater wetlands are designed in “zones” that support diverse aquatic vegetation to provide greater nutrient uptake, pollution filtration, and storage capacity, while not using much more space than a wet pond.

FAQ: But what about mosquitoes?

Wetlands are actually less likely to have mosquito issues than wet ponds! Constructed wetlands incorporate plants that attract natural mosquito predators, like dragonflies, whereas wet ponds have more uninterrupted space for mosquito breeding to occur.

CONSTRUCTED WETLAND COMPONENTS



1 - COLLECTION: Stormwater flows into the wetland from nearby parking lots and rooftops. Upon entry, heavier soil particles settle to the bottom to keep from clogging the wetland.

2 - "NATURE'S SPONGE": Stormwater then flows through a series of shallow pools and channels filled with wetland plants. The plants trap sediment and absorb nutrients, like nitrogen and phosphorus, which can cause harmful algal blooms.

3 - POLLUTANT BREAKDOWN: The soil and root systems of wetland plants support a thriving community of microbes. Microbes break down organic pollutants, such as oils and grease, to improve water quality.

4 - FINAL TOUCHES: After flowing through the pools, the treated stormwater leaves the wetland through an outflow structure. The water flows more slowly and is less polluted than when it entered, protecting downstream waterways from erosion and flooding and improving water quality.

WETLAND ZONES

ZONE	COLOR CODE	WHEN IS IT WET?	WATER DEPTH
Deep Pools		Drought Conditions	>18 in
Shallow Water		Normal Conditions	2-4 in
Temporary Inundation		After Rainstorms	0-12 in
Upper Banks		After Very Large Rainstorms	N/A

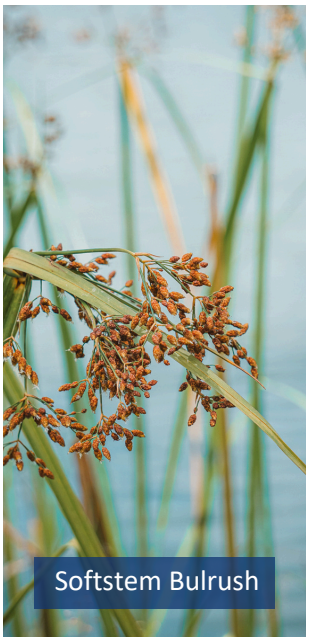
FAQ: Can I convert an existing wet pond to a wetland?

Yes, and we encourage you to do so if you can! While the above example is slightly undersized for permitting purposes, you can see that wetlands don't have a much bigger footprint than wet ponds. With some tweaks to the design, it's an accessible conversion to make!


Pickerelweed

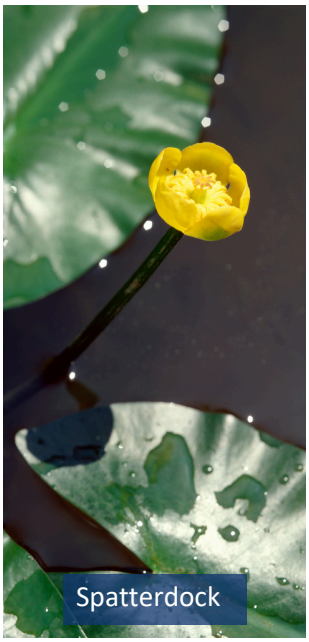

Bulltongue Arrowhead


Lizard's Tail


Softstem Bulrush


Broadleaf Arrowhead


Swamp Rose Mallow


Spatterdock


Woolgrass


Carex sedges


Common Rush

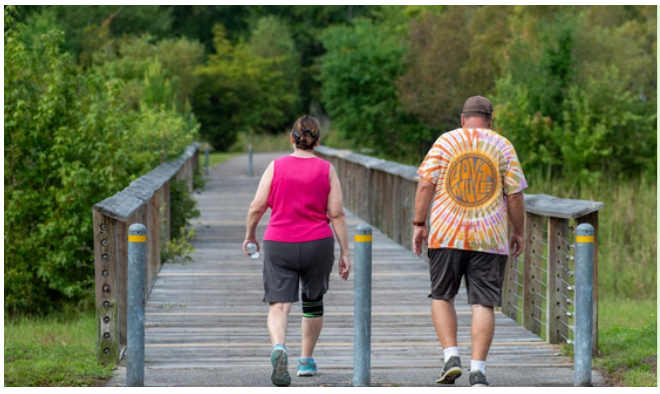

Swamp Sunflower

CONSTRUCTED WETLAND BENEFITS

Resiliency & Streambank Stabilization
Constructed and natural wetlands are a key player in building resilient communities. They provide capacity for flood storage and the vegetation helps to stabilize shorelines to prevent erosion. Wetland buffers are commonly used to restore floodplains and streams.

Pollution Treatment & Removal
Wetlands are natural filters. Rather than relying solely on sedimentation to "settle out" pollutants, like ponds, wetland plants slow down and actively filter out pollutants as runoff flows through the various wetland zones.

Wildlife Habitat & Corridors
Wetlands are wildlife havens and have some of the highest biodiversity of all ecosystems. From amphibians and insects to fish and birds, wetlands provide protected habitat and nursery areas in urbanized spaces.



Community Amenity & Aesthetics
Wetlands can provide recreational opportunities such as walking, biking, bird-watching, and more. Designing them with the community in mind can provide a valuable amenity while also providing green space and downstream water quality improvements.

SUMMARY COMPARISON

	Wet Pond	Wetland
Size	Medium - Large	Medium - Large
Construction Costs	Medium	Medium
Maintenance Level	Medium	Medium
Wildlife Benefits	Medium	High
Community Amenity	Medium	Medium - Large
Algal Bloom Risk	High	Low - Medium
Pollution Treatment	Medium	Medium - High

DESIGN & CONSTRUCTION

If being used to fulfill permit requirements, please refer to the NCDEQ Stormwater Design Manual, C-4, for the stormwater wetland Minimum Design Criteria.

The major elements of a constructed wetland include:

- An inlet and outlet
- A forebay for sediment collection
- Non-forebay deep pools to retain water
- Shallow water zone to keep a hydraulic connection through the wetland
- Temporary inundation zone for pollution treatment
- Wetland plants suited for shallow and deep-water zones

Not all stormwater wetlands will look the same, so keep goals, space, and budget in mind.

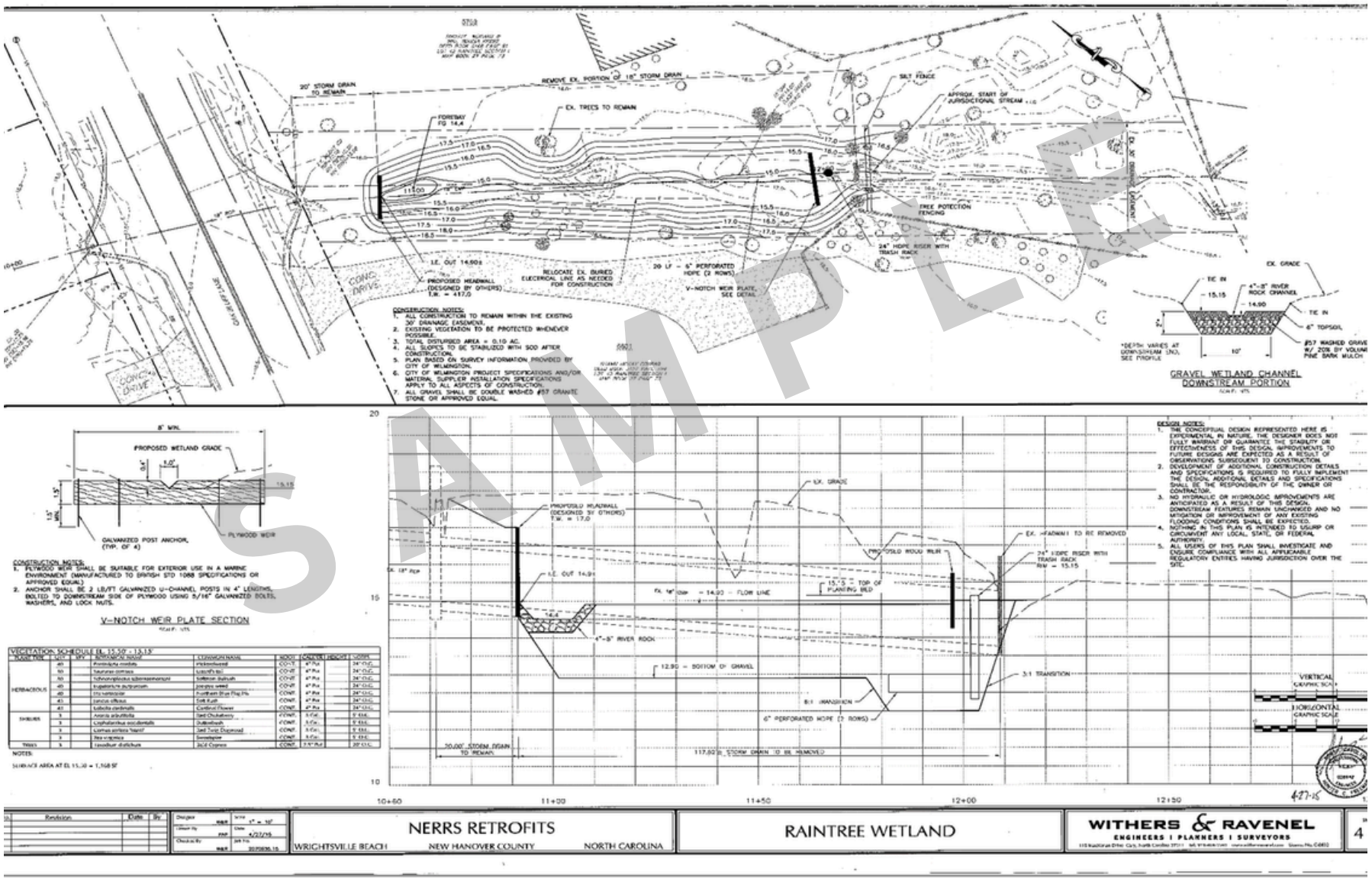
For additional considerations, NC State University's "Stormwater Wetland Construction Guidance" includes additional details, such as plant calculations, construction sequencing, soil preparation techniques, outlet structure installations, site stabilization, and more.

The guidance document is available at content.ces.ncsu.edu/stormwater-wetland-construction-guidance

Example of an inlet during construction *(Photo Credit: City of Wilmington)*

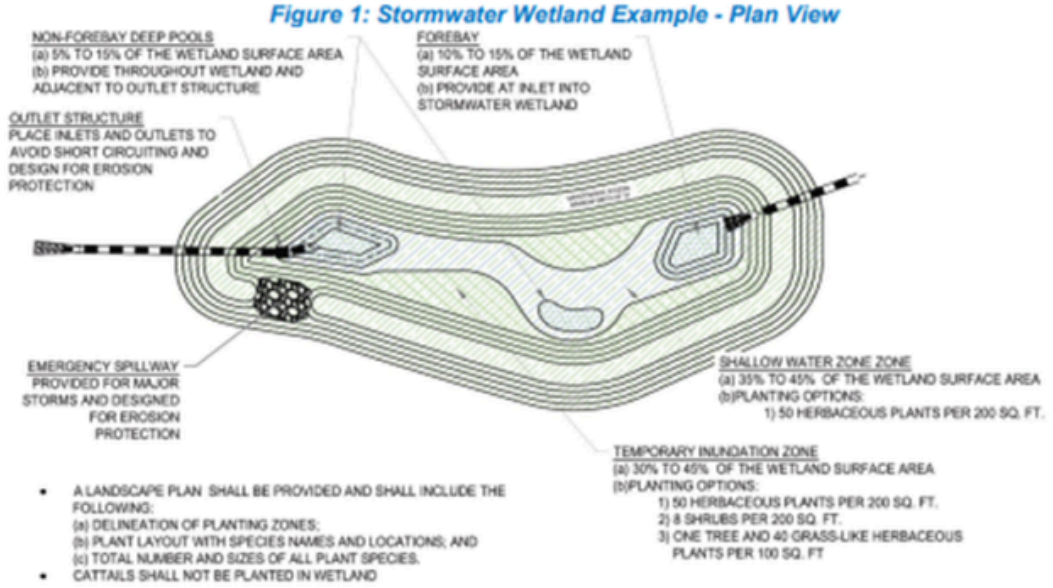
Channels may require added river rock or other soil modifications *(Photo Credit: City of Wilmington)*

All stormwater wetlands should have an outlet though the design may differ *(Photo Credit: Hunter Freeman)*



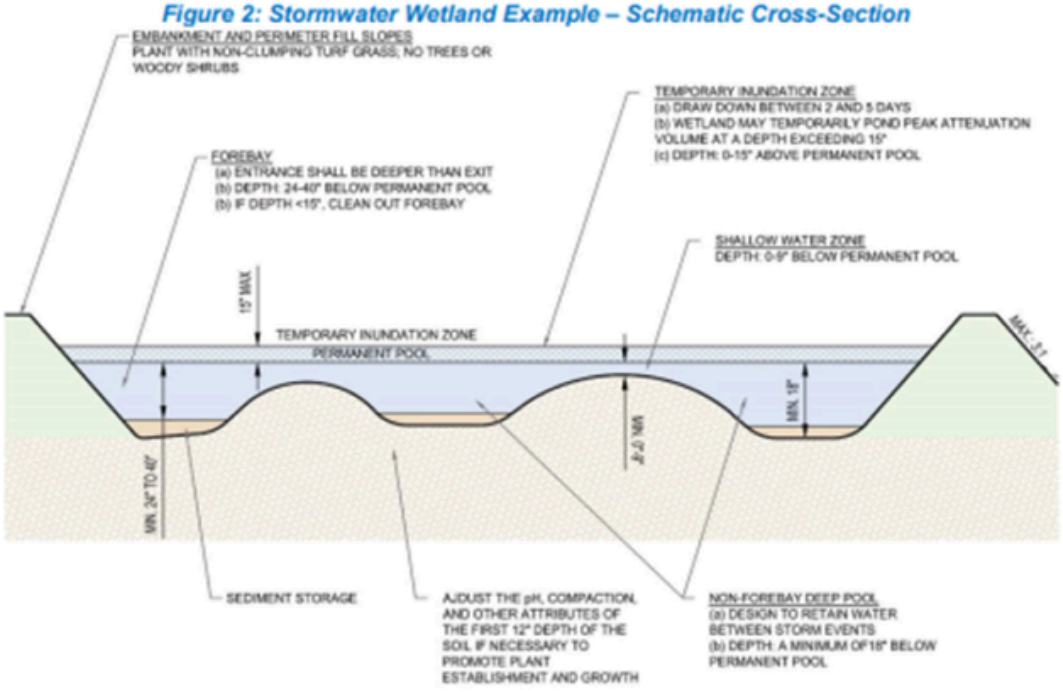
An example constructed stormwater wetland schematic, created for the City of Wilmington's Raintree Wetland.

Figure 1: Stormwater Wetland Example - Plan View



- A LANDSCAPE PLAN SHALL BE PROVIDED AND SHALL INCLUDE THE FOLLOWING:
  (a) DELINEATION OF PLANTING ZONES;
  (b) PLANT LAYOUT WITH SPECIES NAMES AND LOCATIONS; AND
  (c) TOTAL NUMBER AND SIZES OF ALL PLANT SPECIES.
- CATTAILS SHALL NOT BE PLANTED IN WETLAND

Figure 2: Stormwater Wetland Example – Schematic Cross-Section



Page 3 of the NCDEQ Stormwater Design manual shows example designs for stormwater wetlands.

WETLAND CARE TIPS & TRICKS

Establishing a Newly Constructed Wetland

Not all stormwater wetlands will function or act exactly the same way, but there are many similarities when it comes to establishing a brand new constructed wetland. Below are some tips and tricks to help a constructed wetland start on its path to success:

- Try to plan plantings for spring or fall, as new plants are especially susceptible to heat and drought conditions
- Have a watering plan in place to address any gaps in rain, i.e. irrigation, watering trucks, etc.
- If there has been a lot of rain, keep water levels in the wetland below 6 inches to prevent drowning new plants
- Watch out for nuisance geese that eat small plants
- Incorporate a contingency budget to account for plant losses in the first two years

Maintaining a Constructed Wetland

Success of any Stormwater Control Measure heavily depends on how well it is maintained, and constructed wetlands are no exception. The good news is that, once established, wetlands take care of themselves pretty well and need mainly supportive and preventative maintenance. Key maintenance tasks include:

- Removing litter and other debris that can clog the system
- Removing invasive plants and animals (ideally before they become established)
- Regularly inspecting the inlets and outlets for blockages or any needed repairs
- Removing and properly disposing of collected sediment

Performing these tasks regularly, or hiring a contractor specialized in wetlands management, will keep wetlands healthy and working properly.

EXAMPLE: COMMERCIAL WET POND TO WETLAND CONVERSION

University Commons - Established 2024

The University Commons wetland was originally built as a wetpond in the early 2000s. It treats a 20 acre commercial complex consisting primarily of retail stores and associated parking. In 2024, it was redesigned as a wetland to improve water quality treatment and increase infiltration capacity. In doing so the surface area increased by approximately 30% and outlet structure was altered to maintain a shallow normal pool and safely route large storm events.

Highlights

- Total Cost: $105,000
- Monthly Costs: $2,000
- Size: 150,000 sq. ft.
- Capacity: 1.5" (Water quality storm)
- Drainage area: 20 acres

EXAMPLE: MIXED-USE DEVELOPMENT

Park West Village – Town of Morrisville

The wetland at Park West Village in the Town of Morrisville is a prime example of a private wetland designed for stormwater management within a mixed-use development. Spanning 100 acres, the property features a town center, retail stores, restaurants, residential units, office spaces, and a 750,000-square-foot movie theater. Established in 2015, the wetland is situated at the heart of the site, offering walking trails and a playground for visitors. Dragonfly Pond Works oversees its maintenance, which involves controlling invasive species, avoiding removal of native species, and managing trash and debris. More details and photos can be found at: www.dragonflypondworks.com/blog/constructed-wetland-stormwater

Highlights

- Total Cost: $750,000
- Monthly Costs:$2,000
- Size: 150,000 sq. ft.
- Capacity: 6’ (100-yr storm)
- Drainage area: 69 acres

EXAMPLE: RESIDENTIAL NEIGHBORHOOD

Raintree Wetland - Established 2015

Raintree Wetland is a City of Wilmington owned and maintained wetland located within the Raintree neighborhood. This is an example of how a residential constructed wetland can blend into existing drainage infrastructure. This wetland was constructed in a drainage easement between two homes by City of Wilmington staff and treats stormwater runoff from the surrounding impervious surfaces. Regular watering was required while the plants became established, but now maintenance is minimal. Current tasks include removing trash, sediment, and invasive species

Highlights

- Total Cost: $41,544.73
- Size: 1,168 sq. ft.
- Capacity: 2,920 cu. ft.
- Drainage area: 8.9 acres
- Pollutant Removal Rates
  - TN: 1.24 lbs/yr
  - TP: 0.13 lbs/yr
  - TSS: 113.07 lbs/yr

EXAMPLE: COMMUNITY PARK

Wade Wetland - Established 2007

Wade Wetland is the largest constructed wetland within the City of Wilmington. The property was established through a City-County partnership with a grant from the Clean Water Management Trust Fund. Native wetland plants are well-established, so maintenance is very limited. Typical maintenance tasks include mowing the perimeter, keeping signage updated, removing trash, and removing any invasive plants.

Highlights

- **Total Cost: $4,360,000**
- **Size: 12 acres**
- **Capacity: 650,000 cu. ft.**
- **Drainage area: 590 acres**
- **Pollutant Removal Rates:**
  - **TN: 249.14 lbs/yr**
  - **TP: 26.60 lbs/yr**
  - **TSS: 19,257.82 lbs/yr**

EXAMPLE: COMMUNITY PARK

Mary Bridgers Wetland - Established 2004

The Mary Bridgers Wetland is located within the Burnt Mill Creek Watershed and was constructed during the implementation of a 319 EPA Grant. This wetland is located directly between a residential area and Burnt Mill Creek. A bridge crosses the wetland, showing how a constructed wetland can be amenitized as a park or open space area for people to enjoy. Monitoring data after construction suggest that this wetland should have been designed larger to maximize treatment, but there are still improvements in nitrate and ammonium removal. Regular maintenance currently includes trash removal, mowing, and removing invasive species.

Highlights

- Total Cost: $28,946
- Size: 8,605 sq. ft.
- Capacity: 1.5 cu. ft.
- Drainage area: 15 acres
- Pollutant Removal Rates
  - 63% Decrease in Ammonium
  - 40% Decrease in Nitrate

REGS & RESOURCES

Regulatory Agencies

Please refer to the **local governing body** for the property for local ordinance, design, and maintenance information. For example, **properties within the City of Wilmington, NC** should visit wilmingtonnc.gov/Development-Business/Development-Review/Stormwater-Permits for information regarding plan review, stormwater permits, and Operation and Maintenance agreements.

All other questions should be directed to the **North Carolina Department of Environmental Quality (NCDEQ)**. Comprehensive information about constructed stormwater wetlands and other Stormwater Control Measures (SCMs) can be found in the latest version of the **Stormwater Design Manual** at www.deq.nc.gov/about/divisions/energy-mineral-and-land-resources/stormwater/stormwater-program/stormwater-design-manual.

Available Incentive/Grant Programs

For properties located within the City of Wilmington, NC:
BRADLEY & HEWLETTS CREEKS COST-SHARE PROGRAM: Commercial, mixed-use, multi-family, community, and HOA Common Area properties located within the Bradley Creek and Hewletts Creek watersheds are eligible for **up to $20,000** in green infrastructure rebates. Proposed projects must go above the required stormwater treatment and be approved prior to construction. For more information and to schedule a consultation, visit **www.healourwaterways.org**.

For properties located in unincorporated areas of New Hanover County:
NEW HANOVER COUNTY WATER QUALITY IMPROVEMENT PROGRAM: Properties in New Hanover County unincorporated areas are eligible for up to 50% cost-share for green infrastructure practices, either through monetary payment or pay-in-kind through assisted labor during installation. Visit **www.nhcgov.com/789/NHC-Water-Quality-Improvement-Program** for more information.

Available Statewide:
COMMUNITY CONSERVATION ASSISTANCE PROGRAM: Commercial and residential properties that have been developed for three or more years are eligible for **up to 75% cost-share** for green infrastructure practices. Contact your local Soil and Water Conservation District for more information.
New Hanover County Soil and Water Conservation District website:
www.nhcgov.com/255/Soil-Water-Conservation-District

DEFINITIONS

BMP - Best Management Practice. Any action or on-the-ground practice that reduces the amount of stormwater and pollution flowing into waterways. For example, rain gardens and rain barrels are structural BMPs, and picking up pet waste is an active BMP.
BOD - Biological Oxygen Demand,
CFU - Colony Forming Unit, used to measure fecal coliform concentrations.
CWA - Clean Water Act
Cyanobacteria -
EPA - US Environmental Protection Agency
Erosion - The natural breakdown of rock to soil by time, weather, and other elements.
Fecal Coliform - Bacteria present in the intestines and feces of warm-blooded animals. High levels of fecal coliform bacteria in a waterway can indicate the presence of other disease-causing organisms.
Forebay - A small reservoir in a wetland, pond, or other SCM that functions to slow down runoff, and collect trash and sediment before flowing into the main body of the SCM.
Flow - The volume of water, often measured in cubic feet per second (cfs), flowing in a stream or through a stormwater conveyance system.
Green Infrastructure - Stormwater treatment that mimics natural processes to treat and soak in stormwater runoff at the source. Examples include rain gardens, rain barrels, and permeable pavement. Can be used interchangeably with nature-based stormwater solutions.
HAB - Harmful Algal Bloom,
Hydrology - The study of all states of water and the water cycle. Can also refer to the natural drainage patterns of a site.
Hypoxia - When dissolved oxygen in the water is too low to support aquatic life; often leads to fish kills.
Impervious Cover - A hard surface area, such as a parking lot or rooftop, that prevents water from soaking into the ground and creates stormwater runoff.
Infiltration - The process of water entering and flowing downward into the soil, where it can then replenish groundwater or be taken up by plant roots.
MDC - Minimum Design Criteria
Microbes - Tiny living organisms that require a microscope to be seen.
Nature-Based Stormwater Solution - A practice that mimics a site's natural hydrology to treat and infiltrate stormwater runoff at the source, such as a rain garden or constructed wetland.
NCDEQ - North Carolina Department of Environmental Quality
Nutrients - Substance that supports vegetation growth, such as Nitrogen and Phosphorus.

Outflow/Outlet - An exit point for runoff to flow through.
Permeable/Pervious - A surface that water can soak through, such as grass, sand, or permeable pavement.
Retrofitting - The process of adding improvements to an established site that were not already there, such as converting a parking lot into permeable materials or adding a rain garden to a residential property.
SCM - Stormwater Control Measure, more commonly used now than BMP, describes any practice used to manage and/or treat stormwater runoff. Nature-based practices are also SCMs, but not all SCMs are nature-based practices.
Stormwater Runoff - Water from rain that flows over the land surface, picking up pollutants that are on the ground.
UNCW – University of North Carolina at Wilmington
Watershed – An area of land, governed by the topography, that drains to a specific body of water such as a creek, lake, or river.
Wet Retention Pond -
Wetland - An area of land that is wet periodically or permanently and supports diverse vegetation and wildlife. Can be naturally occurring or man-made.