SWAMP

The Stream and Wetland Assessment Management Park

The Duke University Wetland Center
Nicholas School of the Environment
Durham, NC

THE DUKE UNIVERSITY WETLAND CENTER'S STREAM & WETLAND ASSESSMENT MANAGEMENT PARK (SWAMP) IN THE NORTH CAROLINA PIEDMONT

1. INTRODUCTION and PROJECT SUMMARY

The Stream and Wetland Assessment Management Park is on a restored section of the Sandy Creek stream and floodplain within Duke Forest near Duke University's West Campus. Water quality in Upper Sandy Creek, a headwater for the Cape Fear River in the North Carolina Piedmont, has for years been impaired by high N and P concentrations, sediment load and coliform bacteria. To address these problems, the restoration activities included the following:

- **Recontour and replant more than 600 meters of degraded stream to hydrologically reconnect the stream with the adjacent floodplain and allow natural riparian wetland biogeochemistry transformations to improve stream water quality.**
- **Build an earthen dam and 1.6-hectare (ha) stormwater reservoir to regulate stormwater delivery to downstream water bodies, replace a deteriorating dam farther downstream, and allow for additional retention and removal of excess nutrients and sediments from the stream. Water levels in the reservoir will be controllable for research purposes.**
- **Build a 0.5-ha treatment wetland to intercept and improve the water quality of a tributary stream impacted by high concentrations of N and P.**
- **In 2009, 2 years after the dedication of the initial 3-phase project, construction began on the restoration of another tributary branch of Sandy Creek that receives runoff from 210 acres on and around Duke West Campus.**

  In 2012, a 0.4-acre Best Management Practices (BMP) extended-detention stormwater wetland was built along Duke University Road to promote retention and settling of pollutants and sediment. Restoration of 734 linear feet of an unnamed tributary adjacent to the BMP was completed in 2014.

The 3.2-ha SWAMP ecosystem serves as an outdoor classroom and field laboratory for students and researchers and provides a site for research on biological diversity, hydrology, mosquito control, invasive plant species and other environmental concerns. Signs along the trail and boardwalks into the site inform the public about the project and the role of wetlands in promoting water quality.

2. DEFINING THE PROBLEM

Upper Sandy Creek is a state-designated Natural Heritage Program Priority Area (NCDENR, 2001) and a headwater for the Cape Fear River watershed in the North Carolina Piedmont.

Headwater wetlands are important for improving water quality and quantity in the watershed and for reducing storm runoff. Unfortunately, most of the headwater wetlands in North Carolina's Piedmont are presently in a disturbed state.

EPA has expressed a distinct concern about degraded water quality in the tributary watersheds that feed Jordan Lake reservoir. Stormwater from about 1,400 acres of Durham, NC, including much of Duke's campus, drains into Sandy Creek, carrying heavy concentrations of sediment and urban pollutants. Sandy Creek is a tributary of New Hope Creek, which meets all state pollution standards when it enters northern Durham County but often is in violation by the time it leaves southern Durham County bound for Jordan Lake, part of the region's drinking water reservoir.

New Hope Creek's poor water quality had historically been due to high nutrient concentrations (N and P), sediment load, and coliform bacteria between the confluence with Sandy Creek and its terminus in Jordan Lake, suggesting that Sandy Creek had been a significant source of impaired waters (NC DENR, 2003).

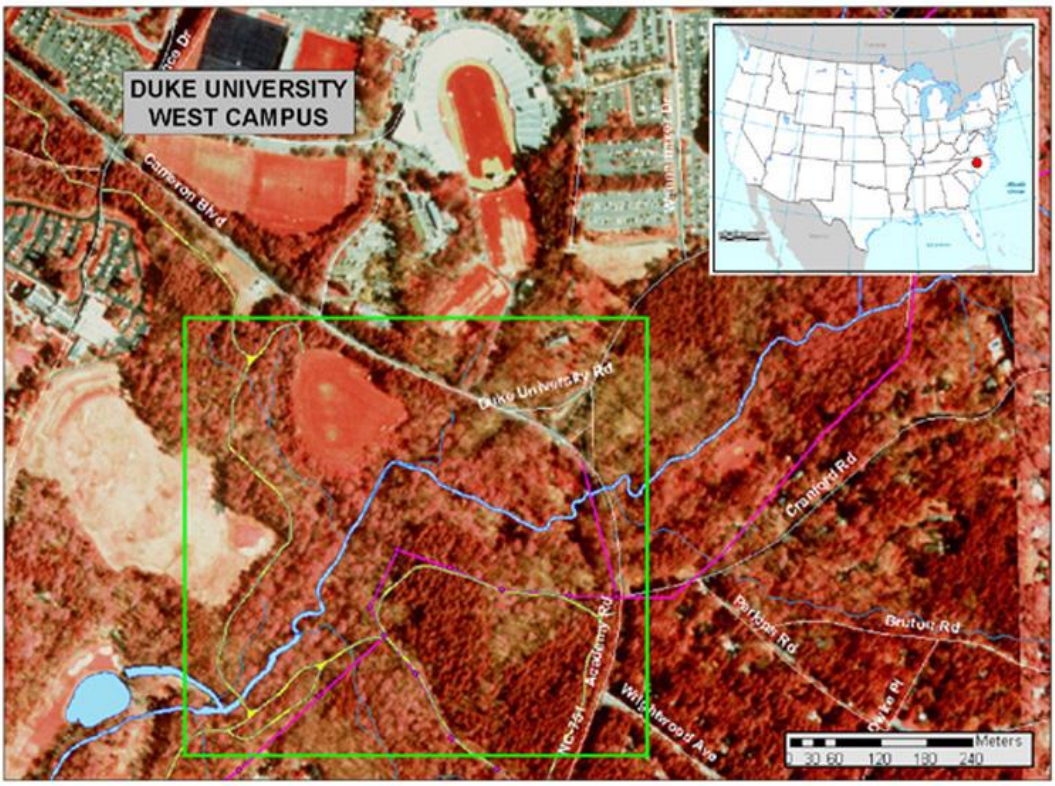

Figure 1. Original state of Sandy Creek, shown in a 1998 FCIR image in relation to Duke University West Campus. The green box indicates the general location of the DUWC restoration project. Notice the two linear sections of Sandy Creek just south of Cameron Boulevard, and the proximity of the Duke Forest jogging trail (yellow) and the City of Durham municipal sewer (pink).

The Upper Sandy Creek floodplain (Figure 1) was impaired due to:

- **Nutrient-rich stormwater runoff inputs from Duke University West Campus and adjacent suburban and urban development**

- **Rapid rates of erosion within the creek system due to an incised and straightened stream profile (Figure 2) associated with high percentages of impervious surface (20.6%) in the 497-hectare watershed and rapid deliveries of drainage following storm events**

Figure 2. Photograph of Sandy Creek prior to restoration. The high degree of channel incising is evident. In places, the stream was incised as much as 2.5 meters below bankfull.

- **A disconnected hydrology between the creek and the adjacent floodplain due to channel incising**

- **Elevated fecal coliforms (Figure 3) from adjoining municipal sewer lines (See Figure 1) that can and do overflow during storm events.**

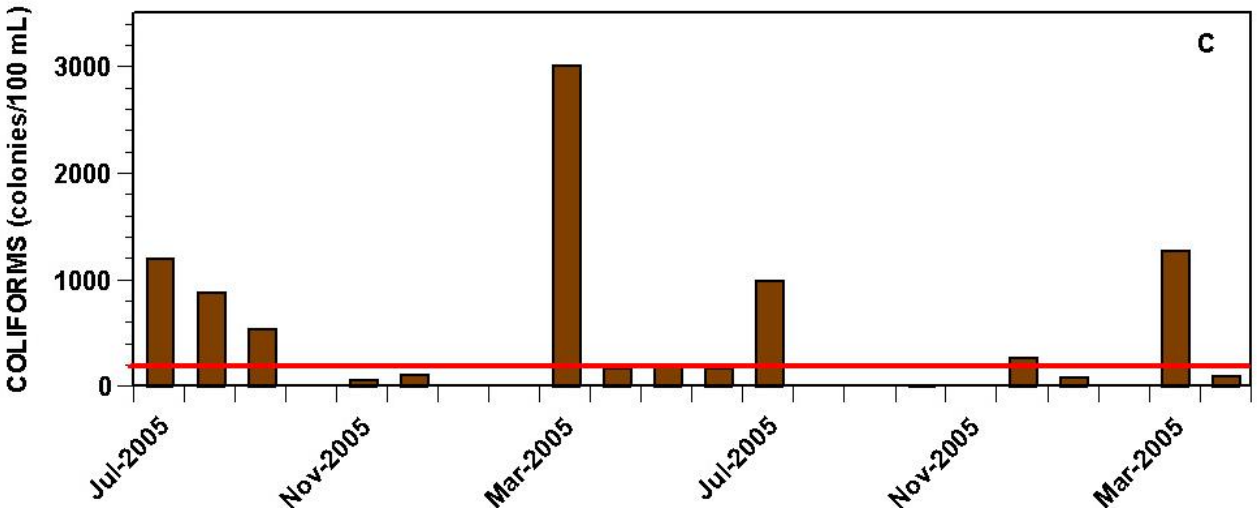

Figure 3. Fecal coliform counts measured on water samples taken from July 2003 through April 2005 where Sandy Creek enters the project area under Academy Road. The red line indicates both the US EPA and NC DENR criteria of 200 colonies per 100 mL of sample, which is frequently exceeded in Sandy Creek.

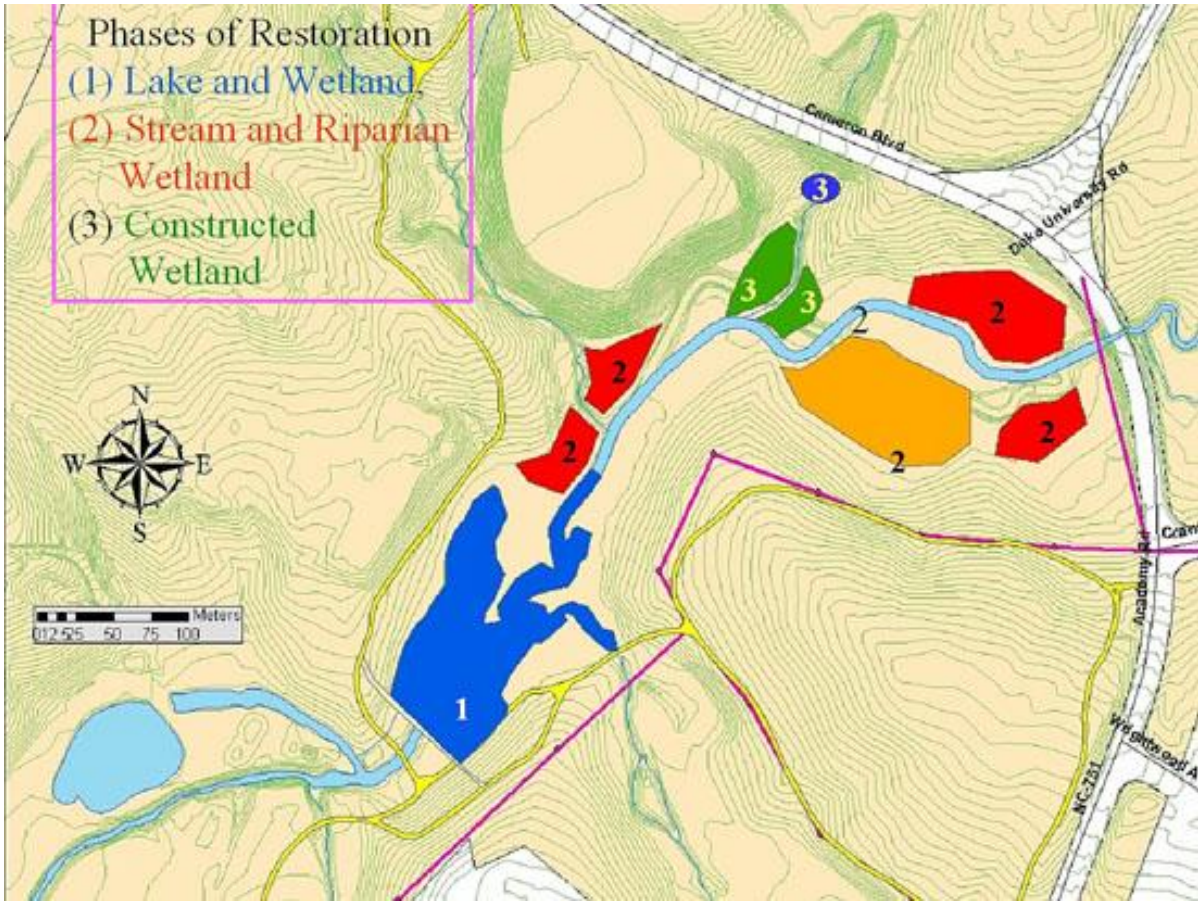

Figure 4. The restored section of Sandy Creek and its related floodplain (Phase 2) are shown in relation to the SWAMP research plots (biodiversity experiment in orange and invasives experiment in red). The Phase One dam and impoundment are shown in dark blue and the Phase Three treatment wetland in green. The impoundment is approximately overlaid on the 294 contour line, while the Phase Three treatment wetland is on the newly realigned tributary stream.

3. THE ORIGINAL THREE-PHASE PROJECT

The original three-phase restoration of the Upper Sandy Creek floodplain (Figure 4) was developed in conjunction with the Duke University Wetland Center, Duke Forest and the Dept. of Civil and Environmental Engineering. Planning began in 1998, with construction of Phase 1 beginning in late 2003.

PHASE ONE: STREAM RECONTOURING & FLOODPLAIN RE-ESTABLISHMENT

Goals: Completion of this phase promoted overbank flooding during storm events, thereby re-establishing the hydrologic link between the stream and floodplain and fostering biogeochemical transformations of stormwater.

Figure 5. A photo of the re-contoured stream. Compare the morphology of this section with the pre-restoration channel shown in Figure 2.

PHASE TWO: DAM AND IMPOUNDMENT CONSTRUCTION

Goals: Completion of this phase will further promote reductions in nutrients via biogeochemical processing in and on the fringes of the impoundment and also reduce fecal coliform and sediment content by promoting sedimentation.

Figure 6. A. Wetland Center faculty and students inspect the dam during construction. B. With construction complete, a bridge for Duke Forest's Al Buehler Cross Country Trail crosses the top of the dam.

Figure 7. With the dam completed and the weir installed, we can now vary impoundment volume and depth.

PHASE THREE: CONSTRUCTION OF STORMWATER TREATMENT WETLAND

Goals: Completion of this phase will reduce high concentrations of nitrogen and phosphorus associated with campus stormwater runoff entering Sandy Creek.

Phase 3 was designed to enhance water quality of Upper Sandy Creek and Jordan Lake. The recontoured channel now consists of three terraced stream sections connected by rock steps, which is designed to slow the stream's flow, aerate the water with oxygen and increase the quantity and frequency of stream bank overflow. Over bank flooding during storm events is a natural process in riparian (steam-related) systems, reducing the velocity of stormwater flow and encouraging sediment deposition. The surrounding floodplain wetlands are also terraced for increased water retention time to reduce high nitrogen and phosphorus concentrations associated with campus stormwater runoff. Nitrogen and phosphorus deposited in sediments are processed by bacteria in the soil, taken up by herbaceous wetland vegetation, and are no longer free to flow downstream.

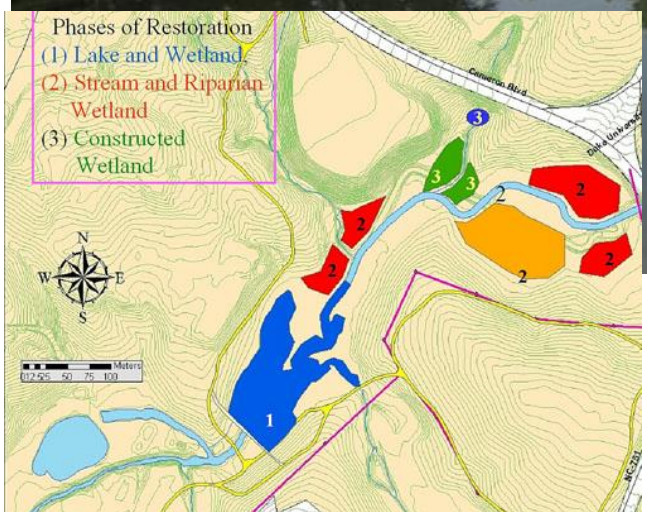

Figure 8. Phase Three as it appeared in 2006 shortly after construction was completed. The inset map shows the location of Phase Three (in green) in relation to Phases One and Two.

The three-phase SWAMP site was officially dedicated at a public ceremony in May 2007. The dedication program, hosted by DUWC Director Curtis Richardson, included remarks by Duke Provost Peter Lange, Executive Vice President Tallman Trask III and Dean William Schlesinger.

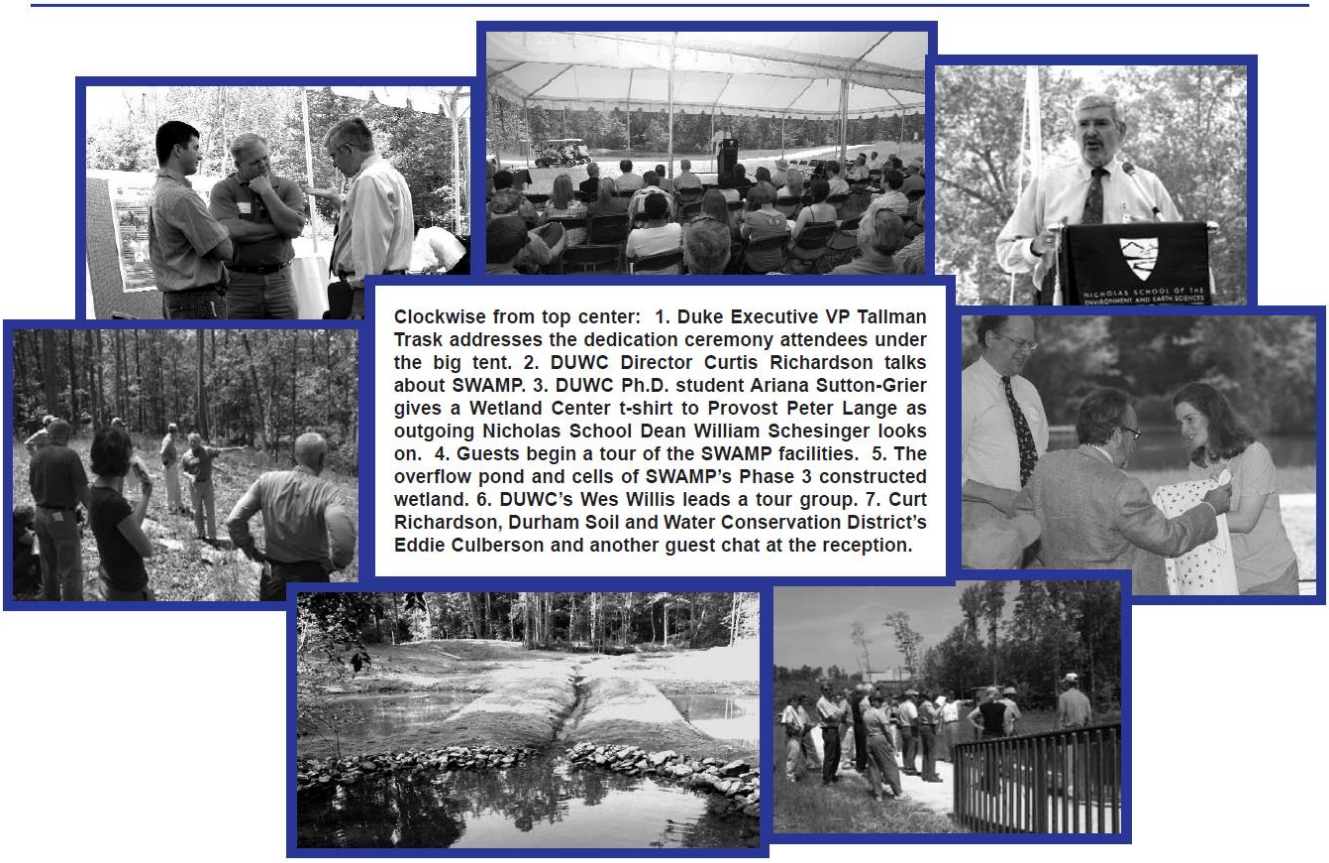

Figure 9. A photo montage from the 2009 SWAMP dedication ceremony, originally published in the Fall 2007 edition of DUWC's *WetlandWire* newsletter.

Figure 10. Four Seasons of SWAMP

4. ADDITIONAL PROJECT ACTIVITY

PHASE FOUR: SANDY CREEK UPPER TRIBUTARY PROJECT

In mid-March 2009, construction began on Phase 4 of the In mid-March Stream and Wetland Assessment Management Park, a degraded unnamed tributary of Upper Sandy Creek was reconnected to its original floodplain and to SWAMP's three earlier phases. The project was designed to improve stream flow, hydrologic water retention, and sedimentation prevention in order to improve water quality across 210 acres of the watershed.

The Phase Four site, shown on the map below, lies on both sides of NC-751 south of the intersection with Duke University Road. The degraded creek, shown below, was deeply incised, eroded, and clogged with sediment.

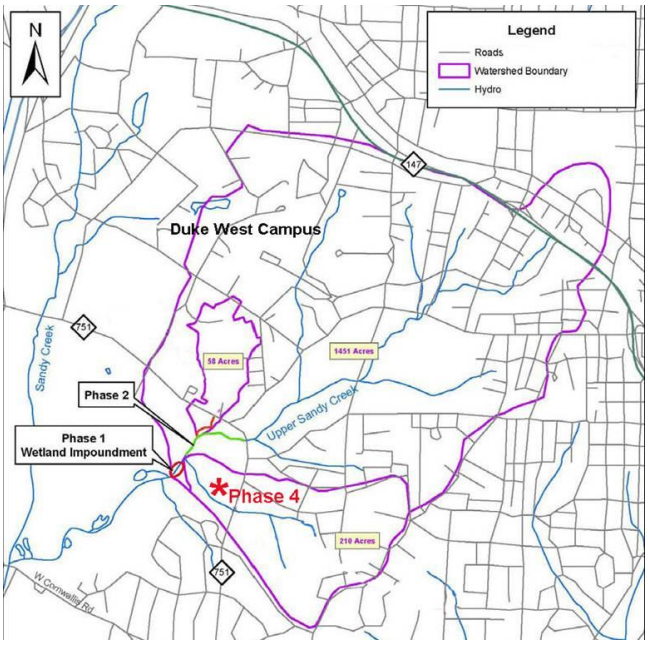

Figure 11. The map shows the location of the Phase Four project site and 210-acre watershed. The stream channel at the location was deeply incised.

Figure 12. Machinery moves gingerly to restore a section of degraded stream channel while protecting the surrounding forest.

The stream has now been recontoured and the channel reconnected to its floodplain in the surrounding bottomland hardwood forest. The photo below, taken in 2010, shows the restoration area shortly after completion. Wetland plants have reestablished themselves in the area since this picture was taken.

In collaboration with the Durham Soil and Water Conservation District and with funding NC's Clean Water Management Trust Fund, the Wetland Center has introduced a new technique called "anabranching." In this technique, small weir structures in the channel will make it possible for researchers to vary both the amount and periodicity of flood-plain connectivity to a greater degree than had been previously possible, allowing more contact between the stream and its riparian wetland floodplain. The project will allow Duke researchers to collect comparative data on a variety of restoration techniques.

Figure 13. Phase 4 channels shortly after the completion of construction

DESIGN and CONSTRUCTION SPONSORS

Durham Soil and Water Conservation District (Sponsor & Cooperative Agency)

North Carolina Division of Water Quality (Funding Agency)

ADDITIONAL SPONSORS

Duke Forest (Sponsor & Cooperative Agency)

Duke Wetland Center Case Studies Program (Sponsor, Graduate & Undergraduate Research)

USDA Natural Resources Conservation Service (Sponsor, Native Species Plantings)

DESIGN & CONSTRUCTION

Michael Baker Engineering, Inc. Cary NC

River Works, Inc. Cary NC

PHASE FIVE: BMP SITE

Construction began on the first part of SWAMP's Phase Five in April 2012 and was completed by September of that year.

The Phase 5 BMP (Best Management Practices) site is a 0.4-acre extended detention stormwater wetland. It lies along Duke University Road just north of the intersection with NC Highway 751. The stormwater BMP's catchment area is about two-thirds impervious with buildings and parking lots. By retaining stormwater runoff for an extended period rather than letting the water flow quickly down the eroded stream channel through the watershed, the BMP promotes the retention and settling of pollutants and sediment before the water travels downstream to Jordan Lake, a major drinking water source for the area.

Figure 14. The retention area at DUWC's Phase 5 BMP is across Duke University Road from the President's House on Duke West Campus.

Construction on the second part of Phase V, restoration of 734 linear feet of an unnamed Upper Sandy Creek tributary adjacent to the BMP, was completed in 2014. The eroded stream channel had high flows and sediment loads, and it was deeply cut with steep banks. The new meandering stream channel will slow water flow and reconnect the stream to the adjacent wetland.

The project is the result of collaboration between Duke University and the Durham County Soil and Water Conservation District. Funding was provided by the North Carolina Clean Water Management Trust Fund (CWMTF), a program established by the state legislature to issue grants to local governments, state agencies and conservation non-profits to help finance projects that specifically address water pollution problems.

Figure 15. The inflow and outflow structures at the completed Phase 5 BMP site.

5. AN EDUCATIONAL AND RESEARCH RESOURCE

Confining the restoration project to Duke University property has allowed for the development of a research and teaching field laboratory wetland. The restored ecosystem will provide a site for research on biological diversity, hydrology, mosquito control, invasive plant species, and other environmental concerns. Students in wetland restoration classes have gained valuable experience at the site and have made important contributions to SWAMP design features. In addition, the site has unique instructional value as an example of a rare Piedmont wetland. What we learn here will benefit many wetlands and watersheds nationwide. SWAMP is an exciting addition to the Nicholas School's teaching resources.

Figure 16. A DUWC graduate student works on an invasive plants project at a SWAMP research plots.

Figure 17. Students learn hands-on the importance of native plants in the restoration process.

With the completion of Phases One through Four, we have constructed a complex of boardwalks and informational signs. The Durham County Soil and Water Conservation District, with funding from the NC Clean Water Management Trust Fund's innovative stormwater projects initiative, has been a partner in this project. The signs, designed by Maura Nowalk and Randy Neighbarger with input from the entire DUWC community, tell about the SWAMP restoration project and Piedmont riparian ecology. The site is accessible as an educational resource by a wide array of public users from local K-12 students to the professional environmental restoration community.

Figure 18. A DUWC staffer checks on the signs and overlook platform near the Phase IV/Anabranching research site.

Figure 19. Students K-12, undergrads, graduate researchers, and professionals can arrange to tour SWAMP.

Research Articles, Presentations, and Grants

Richardson, C.J. 2017. Conference presentation. *Anabranching Floodplain Connectivity: Biomimicry to Enhance Water Quality Functions in Riparian Ecosystems*. 7th International Wetland Pollutant Dynamics and Control (WETPOL) Symposium. Big Sky, MT. August 22, 2017.

Richardson, C.J. 2017. Webinar. *Integrated Stream and Wetland Restoration: A watershed approach to improved water quality on the landscape.* The Association of State Wetland Managers Webinar Series. July 25, 2017.

Richardson, C.J. 2016. *Novel Stream and Wetland Restoration Approaches to Enhance Ecological Services in Wetlands in Urban Watersheds*. East China Normal University, Shanghai. Invited Speaker. September 24, 2016.

Richardson, C.J. 2016. Conference presentation. *Integrated stream and wetland restoration: A watershed approach to restoring ecosystem functions and services on the landscape.* 10th INTECOL International Wetland Conference, Changshu, China. September 20, 2016.

Dudley, M.P., M. Ho, and C.J. Richardson. 2015. Riparian habitat dissimilarities in restored and reference streams are associated with differences in turtle communities in the Southeaster Piedmont. *Wetlands* 35:147-157. DOI 10.1007/s13157-014-0603-5.

Richardson, C.J. 2015. Conference Presentation. *Integrated stream and wetland design: A watershed approach to restoring ecosystem functions and services on the landscape*. University of Minnesota Water Resources Science Program 2015 Retreat, Sandstone, MN. March 22, 2015.

Deonarine, A., H. Hsu-Kim, T. Zhang, Y. Cai, and C.J. Richardson. 2014. Legacy source of mercury in an urban stream-wetland ecosystem in central North Carolina, USA. *Chemosphere* DOI 10.1016/j.chemosphere.2014.12.038

Ho, M., and C.J. Richardson. 2013. A five year study of floristic succession in a restored urban wetland. *Ecological Engineering* 61(B):511-518 http://dx.doi.org/10.1016/j.ecoleng.2013.05.001

Workshop: Integrated Stream Design in Urban Settings: A watershed approach to restoration. Sponsored by the Duke University Wetland Center and the Durham County Soil and Water Conservation District. May 7 and 8, 2013.

Phase 5 of the Sandy Creek Restoration (Richardson, Durham Soil and Water Conservation District, Clean Water Management Trust Fund, 2012)

Sutton-Grier, A.E., J.P. Wright, and C.J. Richardson. 2012. Different plant traits affect two pathways of riparian nitrogen removal in a restored freshwater wetland. *Plant and Soil* 365:41-57. DOI 10.1007/s11104-011-1113-3.

Long-term changes in community composition and exotic species invasion in a restored wetland in North Carolina (T. Edwards, 2012 Master's Project)

Richardson, C.J., N. Flanagan, M. Ho, and J. Pahl, 2011. Integrated stream and wetland restoration: A watershed approach to improved water quality on the landscape. *Ecological Engineering* 37:25-39.

Unghire, J.M., A.E. Sutton-Grier, N.E. Flanagan, and C.J. Richardson. 2011. Spatial impacts and wetland restoration on riparian soil properties in the North Carolina Piedmont. *Restoration Ecology* 19:738-746.

Winton, R.S., R.L. Neighbarger, and C.J. Richardson. 2011. Conference presentation: *The Effects of Urban Stream and Riparian Restoration on Summer and Winter Avian Populations*. Joint meeting of the Society of Wetland Scientists, WETPOL, and Wetland Biogeochemistry Symposium. Prague, Czech Republic. July 2011.

The Effect of Stream Restoration on Turtle Species Assemblages in the Piedmont Region of North Carolina, USA (M. Nowalk, 2010 Master's Project)

Innovative approaches to stormwater management and water quality improvements in urban watersheds: Upper new Hope Creek, Sandy Creek (North Carolina Clean Water Management Trust Fund Grant; Durham Soil and Water Conservation District, 2010)

A Macroinvertebrate Survey of Sandy Creek in Durham County, NC: A Comparative Study of Post-Restoration and Pre-Restoration Surveys (J. Still, 2009 Master's Project)

Investigating the Spatial and Quantitative Impacts of Stream Restoration on Riparian Soil Properties in the North Carolina Piedmont (J. Unghire, 2009 Master's Project)

Sandy Creek Upper Tributary Project - Phase 4 of the Sandy Creek Restoration (Richardson, Durham Soil and Water Conservation District, 2008)

Exploration of the mechanistic basis and biogeochemical implications of differential nutrient limitation among trophic levels (Richardson, EPA, 2008)

Ecological impacts from the interactions of climate change, land use change and invasive species(Richardson , EPA STAR Grant, 2008)

The Role of Plant Functional Diversity and Soil Amendements in Regulating Plant Biomass and Soil Biogeochemistry in Restored Wetland Ecosystems in the North Carolina Piedmont (A. Sutton-Grier, PhD Dissertation, 2008)

Kazezyilmaz-Alhan, C.M., M.A. Medina, C.J. Richardson. 2007. A Wetland Hydrology and Water Quality Model Incorporating Surface/Ground Water Interactions. *Water Resources Research* 43, W04433, doi:10.1029/2006WR005333

Richardson, C.J. 2006. Conference presentation. *Stream and Wetland Assessment Management Park (SWAMP): A New Approach to Assessing Hydrologic and Water*

***Quality Interactions in Riparian Systems*. Society of Wetland Scientists Annual Meeting, Cairns, Australia, July 13, 2006.**

Richardson, C.J. 2006. Conference presentation. *Changes in Hydrology and Water Quality and Initial Restoration Success During the First Year after Construction of the Duke Forest Stormwater Improvement and Wetlands Restoration Project in the North Carolina Piedmont.* International Conference on Hydrology and Management of Forested Wetlands, New Bern, NC. April 9, 2006.

Quantification of Water Quality Improvement in Sandy Creek, a Tributary Watershed of Jordan Lake in the Cape Fear River Basin, After Stream and Riparian Restoration and Wetland Treatment Cell Creation (Pahl & Richardson, EPA Grant, 2005-2007)

Trajectory of Ecosystem Recovery in Restored Riparian Zones in Urban Settings (Morse, 2005 EPA STAR Grant)

Water Resources Stream Restoration Development Project for Durham County (Richardson, Durham Soil and Water Conservation District Grant, 2005)

The Role of Plant Functional Diversity in Regulating Nitrogen Removal in a Restored Riparian Wetland (Sutton-Grier, NSF Doctoral Dissertation Improvement Grant, 2005-2007)

The Duke Forest Stormwater Improvement and Wetlands Restoration Project: Final Report to the North Carolina Clean Water Management Trust Fund and the North Carolina Ecosystem Enhancement Program. (Richardson and Pahl 2005.)

A Wetland Model Incorporating Overland and Channel Flow, Solute Transport and Surface/Ground Water Interactions (C.M. Kazezyilmaz-Alhan, 2005 Dissertation)

A Macroinvertebrate Survey of Sandy Creek in Durham County and Comparison to Other Triassic Basin Watersheds in North Carolina (B. Roberts, Master's Project)

A Pre-restoration Hydrologic Assessment & Nutrient Budget for Sandy Creek, Durham, NC (R. Elting, 2003 Master's Project)

Integrating the Sandy Creek Restoration Project with Environmental Education (M. Lawrence , 2003 Master's Project)

The Effects of a Wetland Restoration on Water Quality: A Baseline Assessment of Water Quality Indices in the Sandy Creek Project Area, Durham, North Carolina (E. Turley, 2001 Master's Project)

The Effects of Reduced Flooding Frequency on Species Composition in a Bottomland Hardwood Stand in the Piedmont of North Carolina (S. Watts, 2000 Master's Project)

Duke Forest Stormwater Improvement and Wetlands Restoration Project (Richardson, Edeburn and Medina; Cleanwater Management Trust Fund Grant, 1999-2001)