Riding the Storm: How Nature-Based Solutions Can Help Tackle Flooding in Southwest Florida

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MARCH 2025

doi.org/10.33548/SCIENTIA1109

EARTH & ENVIRONMENTAL SCIENCES

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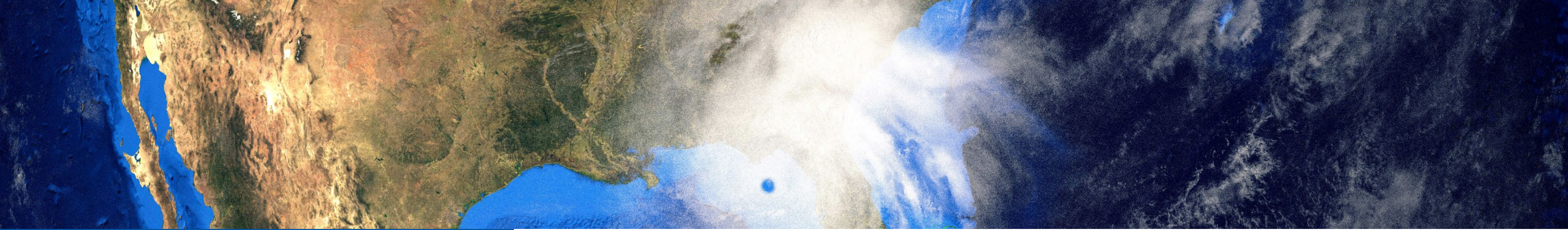


Riding the Storm: How Nature-Based Solutions Can Help Tackle Flooding in Southwest Florida

Florida grapples with mounting challenges related to inland flooding due to heavy precipitation, along with coastal flooding from rising sea levels and coastal storms. One important approach to address precipitation-originating flooding is to embrace land use practices runoff management in the upstream portions of at-risk watersheds, where sustainable design can relieve the pressures on drainage systems from continuing dense urban development in the low-lying Florida landscape. Dr L Donald Duke, from The Water School at Florida Gulf Coast University, plays a pivotal role in this endeavour. His work encompasses creating and evaluating flood-resilient land use practices and planning to manage stormwater runoff on the watershed scale.

Florida's Hidden Flood Threat: Precipitation-Induced Inland Flooding

In Florida, heavy rainfall can cause two types of flooding: coastal flooding (well-publicised during Hurricane Ian) and inland flooding (which inundated even more Florida acreage during the same Hurricane Ian, with much less global publicity). To tackle this, Florida has implemented various programmes at different scales. These range from large-scale projects that reshape vast areas to local regulations for individual homes. Managing water is crucial to prevent flooding, and the South Florida Water Management District (SFWMD) operates an extensive network of canals, levees, water control structures, culverts, and pump stations. Additionally, strict building codes enhance safety, protecting against floods and storms.

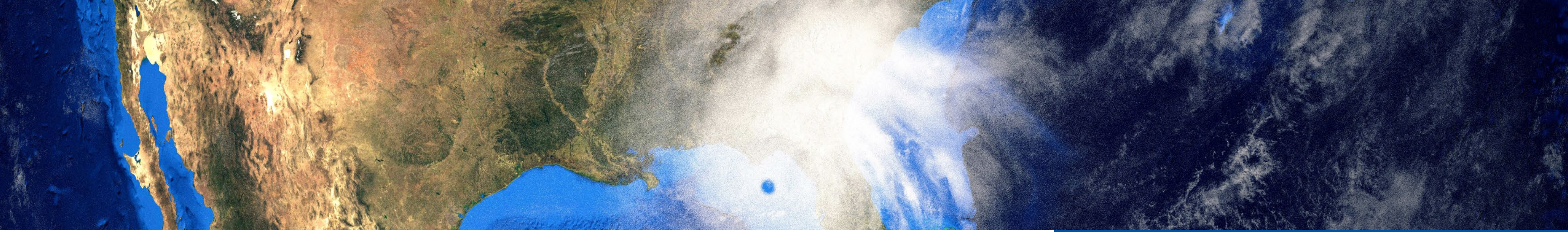
One key approach in managing water and preventing flooding is by detaining runoff in the neighbourhoods where rain falls by managing the landscape to slow flows and mimic natural flow rates. Florida's state-wide policy is known as 'post=pre', which requires post-developed sites to match pre-development hydrology in terms of runoff timing and volume. Many options can be used to achieve this, including allowing landscapes to remain unchanged (which in Florida often means they serve as rain-absorbing wetland) and the use of artificial ponds installed in residential neighbourhoods to capture runoff. These stormwater ponds, widely built in Florida since the early 1980s, serve a dual role; they manage water during heavy rain (volume control) and help improve water quality. However, finding the right balance between the two goals can be challenging.

When it comes to protecting the environment from flooding, there are numerous rules and designs in place, including managing how water flows from sites and reducing pollutants. However, the overall effectiveness of these measures has not been extensively studied.

Unlocking Flood Resilience

Dr L Donald Duke from The Water School at Florida Gulf Coast University (FGCU) and his team investigated three key components that delay stormwater runoff: stormwater ponds (artificial ponds designed to hold excess water), depression storage (water stored in shallow groundwater and seasonal wetlands) and the soil component (where the water table elevation serves as a proxy for soil storage). The main goal of devising an approach to assess how a system manages stormwater runoff was achieved by studying data about runoff retention, storage, and discharge in a specific watershed, the FGCU campus. The researchers assessed the relative effect of stormwater ponds and the two other drainage components. The results constitute a new, concrete way to assess Florida's regulations in effectively preventing flooding from rainfall in developed regions.

Their research uses a case study to conduct a quantitative assessment using real-world data, measuring how ponds' water levels changed during and after major rainstorms. The case study focused on the university campus, which successfully manages runoff while complying with regulations. The data allowed the team also to investigate why FGCU's approach works well to capture excess runoff while nearby developments struggle to detain flows and have contributed to regional flooding in cases like 2017's Hurricane Irma.



Their analysis settled on the campus's hydrologic design featuring large wetlands (some 400 acres of the 800-acre campus) as the explanation for its success in preventing downstream flooding.

Navigating the Deluge: Insights on Flood Mitigation

The research undertaken by Dr Duke and his colleagues demonstrates that when planning and building developments, the design can incorporate different features to manage rainwater and reduce flooding risk. These features help hold back excess water and prevent it from flowing too quickly, which could overwhelm natural water systems and lead to flooding in the surrounding area.

To achieve this, there must be a focus on precise design elements, including how to calculate runoff conditions, maximising the detention capabilities of on-site features (like ponds, wetlands, and soils) to hold water, adopting design conditions based on rainfall frequency, assumptions about system capacity before and during storms, and historical data on storm events. With the well-thought-out use of these features, the FGCU campus has effectively minimised runoff, even during rare heavy fain events. One key reason for this is their large wetland area, which stores excess water beyond what is required by regulations.

Dr Duke's work highlights how the effectiveness of drainage designs depends on various factors, such as water table elevation, pond fluctuation, pool height, and soil saturation. Existing regulations do not consistently promote effective runoff detention to prevent off-site flooding. Unlike regulatory-driven approaches, FGCU's commitment to environmental value led to effective flood management. Other residential developments lack similar incentives and often prioritise structures over runoff-detaining open spaces. Therefore, understanding the interplay between regulations, design, land use choice, and natural components is essential for effective flood mitigation.

These valuable insights into stormwater management strategies emphasise the need for effective site design to prevent flooding in a changing climate and in rapidly developing regions like Southwest Florida.

The Future of Flood Mitigation

Dr Duke believes further research is needed to study how much water flows off surfaces like roads, buildings, and car parks in new developments to better understand the impact of urbanisation on water flow. The different factors which contribute to runoff – such as rainfall, surface materials, and drainage systems – should be taken into account to see how they affect water movements. In addition to real-world observations, computer models are increassingly implemented to simulate runoff before and after development, a much better approach to design multiple components to work together than previous regulations' static specifications of specified pond volume per unit impermeable area. This would allow a better understanding of how these systems successfully handle water runoff after construction in a way that resembles the natural conditions before development.

Further research into component performance is also needed, that is, to understand if all parts of the system are working as expected. For instance, the soil storage component at FGCU is much less effective during wet weather when the water table is high – as near as 1m below the surface in south Florida – and storage in ponds, soils, and wetlands is at a minimum.

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Building on the research by Dr Duke and his colleagues will help refine and improve regulations, assisting in balancing the cost of expanding the drainage system with land-use change. Dr Duke also believes it would be beneficial to understand why ponds behave differently during rainstorms. Exploring a specific parameter to document and categorise ponds based on their behaviour, taking into account factors like the pond's shape, depth, and the surrounding land, as well as the watershed (the area that drains into the pond), would be useful steps forward. Researchers are also developing computer models to estimate how much water flows in and out of ponds during different types of storms.

Finally, Dr Duke's work emphasises the importance of combining structural and non-structural measures for effective flood management. His research provides valuable information for decision-making in flood-prone areas, underscoring the need for a holistic approach to flood management, integrating various strategies to protect communities and promote sustainable development, especially in the face of climate change.

MEET THE RESEARCHER

Dr L Donald Duke, PhD, PE
Professor and Chair, Department of Ecology and Environmental Studies, Florida Gulf Coast University, Fort Myers, FL, USA

Dr L Donald Duke obtained his BSc in Civil and Urban Engineering from the University of Pennsylvania in 1980, as well as a BA in English. He then completed an MSc (1985) and PhD (1992) in Civil and Environmental Engineering, with a concentration in Infrastructure Planning and Management, at Stanford University. He has dedicated over 40 years to a career applying science and engineering tools and data to management and policy decision-making as a private sector consultant, a state-level agency employee, and a University professor. His research has focused on analysing and quantifying the origin, transport, transformation, and fate of chemical and biological constituents in natural waters and watersheds, including designing and assessing the effectiveness of programs and policies to control those pollutants and restore water quality. Dr Duke's contributions to research and policy analysis have been designed to address environmental challenges and promote sustainable practices.

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KEY COLLABORATORS

Dr Serge Thomas, Florida Gulf Coast University

A central theme in much of Dr Thomas's research is to determine ecosystem-level consequences of natural and anthropogenic stresses in aquatic ecosystems. Dr. Thomas works principally with primary producer communities in shallow marine/freshwater hydrosystems, linking ecosystem structure to physico-chemical variation by understanding functional processes at the base of the food web. His research has combined descriptive and experimental approaches to determine causal relationships between biotic and environmental variation.

Dr Rachel Rotz, Florida Gulf Coast University

As Assistant Professor of Hydrogeology, Dr Rotz specialises in the interaction between groundwater and surface water. Her research focuses on groundwater modelling, innovative technologies, and data wrangling, including sensor networks and data analytics. Dr Rotz has contributed to various projects aimed at evaluating water quality and understanding groundwater's role in surface water quality, emphasising the resiliency of water resources in South Florida.

FUNDING

Village of Estero Department of Public Works

Florida Gulf Coast University Communities in Transition Program: Honors College/Office of Undergraduate Research

Florida Gulf Coast University CAS Seidler Fellowship

Whitaker Center for STEM Education/Blair Foundation

Florida Gulf Coast University Water School Research Assistantships

FURTHER READING

LD Duke, *et al.*, Flood mitigation: Regulatory and hydrologic effectiveness of multicomponent runoff detention at a Southwest Florida site, *Journal of the American Water Resources Association*, 2024, 60(1), 189–210. DOI: 10.1111/1752-1688.13157

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