Natural and Nature-Based Infrastructure
Resource Packet for Regional Flood Planning Groups

Flood control projects in Texas have historically relied on conventional "gray infrastructure" solutions. While such projects may be essential in some circumstances to protect lives and mitigate property damage, they are also associated with negative environmental impacts and carry residual risks such as overtopping when capacity is exceeded. As climate variability continues to increase, it is more important than ever to build resilient systems that can adapt to ever changing circumstances.

A Note on Terminology:

Many terms are used to describe natural and nature-based flood mitigation strategies. TWDB rules defines nature based flood mitigation as "mitigation approaches involving the use of natural features, materials, and processes to reduce the risk and impact of flooding." We believe that the goal of these types of projects should center around the conservation, restoration, or emulation of an existing natural ecosystem, which provides essential flood mitigation benefits.

In recent years natural and nature-based flood solutions for flood mitigation have generated great interest and have increasingly been deployed in Texas and across the nation. While gray infrastructure quickly drains stormwater to rivers and streams, increasing peak flows and downstream flood risk, natural and nature-based infrastrastructure works by allowing water to infiltrate where it lands, spreading it across the landscape, and slowing down peak flows.

Unlike gray infrastructure, these natural and nature-based infrastructure projects provide numerous co-benefits to surrounding communities such as improved air and water quality and recreational benefits. Further, nature-based techniques can protect and extend the lifetime of structural investments by deploying a combined or "hybrid approach." For example, bioswales can reduce and delay peak flood heights, which alleviates pressure on stormwater drainage systems during rainfall events, and can extend the lifetime of gray investments.

Below, we have provided an annotated bibliography compiling recent studies and reports on the performance of natural and nature-based infrastructure. These resources can be used to inform the Regional Flood Planning Groups on natural infrastructure techniques as they develop flood management evaluations (FMEs), flood management projects (FMPs), and flood management strategies (FMSs).

Annotated Bibliography

Internal Resources

Glick, P., E. Powell, S. Schlesinger, J. Ritter, B.A. Stein, and A. Fuller. (2020). The Protective Value of Nature: A Review of the Effectiveness of Natural Infrastructure for Hazard Risk Reduction. Washington, DC: National Wildlife Federation.

This report summarizes the latest science surrounding the effectiveness of a wide range of natural and nature-based infrastructure in lowering the risks to communities from floods and other climate-related hazards. The report also highlights key policy reforms needed to mainstream and increase the use of natural infrastructure in communities across the country.

Tags: Latest research; policy recommendations; risk analysis

Texas Living Waters Project. (2020). Houston-Based Recommendations on Natural Infrastructure for Flood Mitigation.

Following catastrophic flooding caused by Hurricane Harvey and with three consecutive years with 500-year storms, a diverse set of stakeholders have published numerous reports in the Houston-area supporting natural and nature-based flood mitigation solutions. This brief report summarizes key green infrastructure techniques, local recommendations and policies to support natural and nature-based flood mitigation.

Tags: Houston area; literature review; recommendations

General Resources

Browder, G., Ozment, S., Rehberger-Bescos, I.; Gartner, T., Lange, G. (2019). Integrating Green and Gray: Creating Next Generation Infrastructure. Washington, DC: World Bank and World Resources Institute.

This report calls for green infrastructure, such as mangroves and wetlands, to play a bigger role in traditional infrastructure planning. The authors argue that integrating nature into mainstream infrastructure systems can produce lower cost and more resilient services. Further, the report also reviews approaches and examples of how to integrate green infrastructure into mainstream project appraisal processes and investments.

Tags: Hybrid infrastructure

Depietri, Yaella & McPhearson, Timon. (2017). Integrating the Grey, Green, and Blue in Cities: Nature-Based Solutions for Climate Change Adaptation and Risk Reduction. 10.1007/978-3-319-56091-5_6.

Through case studies and literature reviews, this chapter explores the role of grey, green, and blue infrastructure and in particular hybrid approaches for disaster risk reduction and climate change adaptation to shed light on available sustainable adaptation opportunities in cities and urban areas. At the same time, the chapter highlights the limitation and drawbacks in the adoption of merely grey or merely green infrastructures and suggests that an intermediate 'hybrid' approach, which combines both blue, green and grey approaches, may be the most effective strategy for reducing risk to hazards.

Tags: Hybrid infrastructure

Gunnell, K., Mulligan, M., Francis, R. A., & Hole, D. G. (2019). Evaluating natural infrastructure for flood management within the watersheds of selected global cities. Science of The Total Environment, 670, 411–424.

This study uses metrics from the WaterWorld model to examine the flood management-relevant natural infrastructure of the upstream watersheds of selected global cities. These metrics enable the characterisation of different types, magnitudes and geographical distributions of potential natural flood storage. The storages are categorised as either green (forest canopy, wetland and soil) or blue (water body and floodplain) and the proportion of green to blue indicates how different city upstream basin contexts provide different types and levels of storage which may buffer flood risk. By mapping the magnitude and types of 'natural' storages in these basins, we have shown that most city upstream basins have a strong reliance on green natural storage which is driven primarily by canopy cover but also soil storage.

Tags: Green vs. blue storage; natural storage; risk exposure

Smith, C.S., B. Puckett, R.K. Gittman, and C.H Peterson. (2016). Living shorelines enhanced the resilience of saltmarshes to Hurricane Matthew. Ecological Applications 28: 871–877.

This study evaluated rock sill living shorelines as compared to natural marshes and hardened shorelines (i.e., bulkheads) in North Carolina, USA for changes in surface elevation, Spartina alterniflora stem density, and structural damage from 2015 to 2017, including before and after Hurricane Matthew (2016). The results show that living shorelines exhibited better resistance to landward erosion during Hurricane Matthew than bulkheads and natural marshes, were more resilient than hardened shorelines, and were able to enhance S. alterniflora stem densities over time when compared to natural marshes. These findings suggest that living shorelines have the potential to improve coastal resilience while supporting important coastal ecosystems.

Tags: Living shorelines; coastal flooding; coastal resilience

Stoner, A. & Hayhoe, K. (2020). Climate Impact Assessment for the City of Houston. ATMOS Research & Consulting.

The Climate Impact Assessment was identified in 2019 as a critical component to creating a safer, more resilient and sustainable Houston. This Assessment links the City's first resilience strategy, Resilient Houston and the City's first climate action plan, Houston Climate Action Plan. The assessment provides downscaled climate trends and projections for Houston to inform the implementation of climate mitigation and adaptation action in the city.

Tags: Climate change; climate vulnerability; flood projections

Sutton-Grier, A. E., Gittman, R. K., Arkema, K. K., Bennett, R. O., Benoit, J., Blitch, S., ... & Grabowski, J. H. (2018). Investing in natural and nature-based infrastructure: building better along our coasts. Sustainability, 10(2), 523.

This study highlights that the implementation of natural and nature-based infrastructure (NNBI) aimed at flood prevention and coastal erosion protection is lagging. However, the researchers argue that there's a present opportunity as the U.S. government reacts to the recent, unprecedented flooding and hurricane damage and considers greater infrastructure investments, to incorporate NNBI into coastal infrastructure projects. The study stresses that doing so will increase resilience and provide critical services to local communities in a cost-effective manner and thereby help to sustain a growing economy.

Tags: Coastal flooding; investments

World Bank. (2017). Implementing nature-based flood protection: Principles and implementation guidance. Washington, DC: World Bank.

The objective of this document is to present five

principles and implementation guidance for planning, such as evaluation, design, and implementation of nature-based solutions for flood risk management as an alternative to or complementary to conventional engineering measures.

Tags: Principles; implementation

Gulf Coast Resources

Bousquin, J. & Hychka, K. (2019). A Geospatial Assessment of Flood Vulnerability Reduction by Freshwater Wetlands–A Benefit Indicators Approach. **Front. Environ. Sci. 7:54.doi: 10.3389/ fenvs.2019.00054.**

This paper details the development of a nationally consistent dataset and a set of high-resolution indicators characterizing where people benefit from reduced flood risk through existing wetlands. Thes dataset can be used at different scales (regional or local) to rapidly assess flood-reduction benefits. The authors used other national scale indicators (CRSI, SoVI) to gauge community resilience and recoverability in Harris County, Texas as a case study. Analysis of the Gulf Coast region and Harris County, Texas identifies communities with both wetland restoration potential and the greatest flood-prone population that could benefit from that restoration.

Tags: Wetlands; flood vulnerability; Harris County; Gulf Coast

Reguero, B.G., Beck, M.W., Bresch, D.N., Calil, J., Meliane, I. (2018). Comparing the cost effectiveness of nature-based and coastal adaptation: A case study from the Gulf Coast of the United States. **PLoS ONE 13(4): e0192132. https://doi.org/10.1371/journal. pone.0192132.**

This study applies a quantitative risk assessment framework to assess coastal flood risk across the United States Gulf of Mexico coast to compare the cost effectiveness of different adaptation measures. These include nature-based (e.g. oyster reef restoration), structural or grey (e.g., seawalls) and policy measures (e.g. home elevation). From the portfolio studied, this study shows that nature-based adaptation options could avert more than $50 billion of costs, and can do so cost effectively with average benefit to cost ratios above 3.5. Wetland and oyster reef restoration are found to be particularly cost-effective. This study demonstrates that the cost effectiveness of nature-based, grey and policy measures can be compared quantitatively with one another, and that investments in nature-based adaptation could meet multiple objectives for environmental restoration, adaptation and flood risk reduction.

Tags: Coastal flooding; cost-benefit comparison; Gulf Coast

Summers, J. K., Harwell, L. C., Smith, L. M., & Buck, K. D. (2018). Measuring community resilience to natural hazards: The Natural Hazard Resilience: Screening Index (NaHRSI)—Development and application to the United States. **GeoHealth, 2, 372– 394. https://doi.org/10.1029/2018GH000160.**

NaHRSI (Natural Hazard Resilience Screening Index) is a tool for communities to evaluate their likely vulnerability and resilience to acute meteorological events like hurricanes, tornadoes, droughts, floods, etc. The index has been applied to all counties of the United States and consists of five major parts examining risk of events, governance to address events, societal, built environment and natural environment attributes that will enhance recoverability for these types of events. By evaluating the factors that influence vulnerability and recoverability, an estimation of resilience can quantify how changes in these characteristics will impact resilience given specific hazard profiles. This study highlights effects of increased development and loss of natural lands on flood risk exposure in the Houston area.

Tags: Vulnerability tool; risk exposure; Texas coast; Hurricane Harvey

Houston Area Resources

FEMA. (2018). Exploration Green! A Case Study in Effective Floodplain Management.

Exploration Green is an ideal example of what is possible as a result of collaboration within a community to achieve long-term, sustainable mitigation of flood-related damage to residential, civic, and commercial structures, while improving quality of life for the people and businesses in the surrounding community. The project involves the conversion of the old public golf course into a public park with five large ponds that will serve as detention basins for excess water during flood events. This report developed by FEMA in 2018 discusses the project and impressive preliminary flood reduction benefits observed after Hurricane Harvey in 2017, when Phase I (out of 5) was just 80% complete.

Tags: Detention and retention; Hurricane Harvey; Houston-Area

Juan, A., A. Gori, and A. Sebastian. (2020). Comparing floodplain evolution in channelized and unchannelized urban watersheds in Houston, Texas. **Journal of Flood Risk Management 13: e12604.**

This study compares the ability of two riverine flood control approaches: channelization and stream preservation/setbacks, to alleviate the adverse impacts of rapid urbanization. While the two watersheds studied (Brays and Buffalo Bayou) are similar in size, topography, and development level, they have contrasting riverine flood management approaches. Brays Bayou is channelized, whereas Buffalo Bayou remains mostly unchannelized. The study found that, while floodplain extent in both watersheds increases over time, the relative change in floodplain extent for Brays Bayou (channelized) is substantially larger than that for Buffalo Bayou (unchannelized).

Tags: Houston; floodplain; channelization; natural channel; urban flood mitigation

Co-Benefits Resources

Bureau of Economic Analysis (BEA). (2019). Outdoor Recreation Satellite Account (ORSA) - Texas 2019. **U.S. Department of Commerce.**

Green spaces are a vital socio-economic component to Texans. In 2019, the state ranked third in the country for GDP and employment contribution related to outdoor recreation. This document reflects the data collected by the Bureau of Economic Analysis, US Department of Commerce, to show economic output generated by outdoor recreational activities such as boating, hiking, etc. The data also highlights the need for protection and conservation of natural resources in the state.

Tags: Co-benefits; recreation; natural spaces; Texas

Guerrero, J., Mahmoud, A., Alam, T., Chowdhury, M. A., Adetayo, A., Ernest, A., & Jones, K. D. (2020). Water Quality Improvement and Pollutant Removal by Two Regional Detention Facilities with Constructed Wetlands in South Texas. **Sustainability, 12(7), 2844.**

This study shows the role of constructed wetlands in improving water quality by reducing pollutants due to stormwater runoff. The researchers compared two regional detention facilities (RDF) with constructed wetlands in McAllen, Texas, through collecting and sampling water quality data for different pollutants over a period of 22 months. The findings revealed a reduction of suspended solids, pollutant concentration and load at both sites for different storm events. The site with larger constructed wetlands and wet detention ponds performed better emphasizing a need of incorporating such hybrid approaches in future detention basins and stormwater management structures in Texas.

Tags: Co-benefits; Water quality; wetland benefits; Texas

Kabisch, N., Korn, H., Stadler, J., & Bonn, A. (2017). Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice. Springer Nature.

This book provides a wealth of resources on the effectiveness of nature-based solutions in addressing climate change adaptation (for instance, chapter 6, as discussed above). A special emphasis on the role of nature-based solutions in creating jobs and stimulating innovation for a green economy is employed throughout the chapters. Chapter 18 discusses different market-based instruments which can help financing nature-based solutions at the local and municipal level. The book also showcases other evidence-based examples to make the case for nature-based solutions in urban areas.

Tags: Co-benefits; green jobs; economy

Spano, G., Dadvand, P., & Sanesi, G. (2021). The Benefits of Nature-Based Solutions to Psychological Health. Frontiers in Psychology, 12.

This article synthesizes recent literature on the association of nature-based solutions with psychological well-being and mental health from different perspectives. The authors provide examples of studies conducted across different disciplines and age groups to show the positive effects of green spaces in improving mood, cognition, and attention, among other benefits.

Tags: Co-benefits; human health

Willis, K. J., & Petrokofsky, G. (2017). The natural capital of city trees. Science, 356(6336), 374-376.

This short article compiles recent research on the natural capital of trees for carbon sequestration, lowering heat island effect, and pollution reduction. It delves further into a focus on specific tree species for maximising these benefits. In addition to providing detailed context of the values provided by urban trees, studies like these are also important to showcase the depth of research on specific nature-based solutions.

Tags: Co-benefits; urban trees; pollution reduction

Texas Living Waters Project

The Texas Living Waters Project is a collaboration of conservation groups working to ensure fresh water, healthy rivers, and flood resilience for all Texans.

NATIONAL WILDLIFE FEDERATION · SINCE 1936 ™

SIERRA CLUB

GALVESTON BAY FOUNDATION

hill country alliance