PRACTICE—LESSONS LEARNED

# Learning From Disaster: What Two Hurricanes Reveal About Ways to Design Public Space as Flood Infrastructure

Anya Domlesky

SWA Group

**Keywords:** flood-adaptive infrastructure, urban resilience challenges, multipurpose design, green infrastructure, coastal parks, riverfront parks

## ABSTRACT

This article examines the resilience of two urban parks in the United States after extreme flooding caused by separate hurricane events. It provides early lessons for designers, planners, and engineers of open and park space from a practice-based research group and two academic partnerships. The first site is coastal, a waterfront park in New York City, New York. The focus was on understanding how elements of the design and construction of Hunter's Point South Waterfront Park, Phase 1, contributed to a high level of resilience during and after Hurricane Sandy, especially related to coastal flooding, storm surge, and heavy rains. The second site is on the principal river system in Houston, Texas. The focus was on understanding how elements of the design and construction of a 160-acre section of Buffalo Bayou Park contributed to a high level of resilience during and after Hurricane Harvey, which brought heavy rains, increased water velocity, and extended submergence.

## INTRODUCTION

Over the past 10 years, there has been increasing support for implementing double-duty infrastructure projects that promise to combine flood-adaptive green infrastructure with conventional grey infrastructure in addition to providing public space. In the United States, a combination of government budget shortfalls affecting public space, infrastructure spending, and climate change risk awareness has contributed to the increasing promotion and construction of these projects in urban areas. There seems to be growing sentiment among project initiators (municipalities, federal agencies like the U.S. Army Corps of Engineers [USACE], and economic development agencies) that building out flood buffers as parks or parks that can serve as floodable space is advantageous. Leading up to this moment, there have been persuasive arguments made variously by those in the natural sciences (environmental scientists, ecologists, and biologists), the social sciences (economists, political scientists, sociologists, and geographers), and professional disciplines (lawyers, engineers, urban planners and designers, architects, and landscape architects) in favor of a double-duty approach. Within these groups, there are arguments for cost savings (Reynaud et al., 2017), the use of scarce land (Le et al., 2019), parks as environmentally high-performing spaces rather than simply recreational amenities (Matos Silva & Costa, 2016; Silva & Costa, 2018), the use of existing assets as climate change infrastructure (Syahirani & Ellisa, 2021), the diversification of disaster management strategies (sometimes to include natural and nature-based features [NNBFs]; Feagin et al.,

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Corresponding Author:
Anya Domlesky
adomlesky@swagroup.com



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2021; Hegger et al., 2016), and the utility of educating visitors about flood mitigation (Kuang & Liao, 2020).

For centuries, parks in urban areas in the United States have been built on land that was either marginally useful for human exploitation of resources (through activities like farming and logging) or very challenging to develop (for inhabitation, commerce, or real estate) due mainly to slope, soil quality, or flooding. The site of what would become Central Park in New York City, for example, was full of bedrock outcrops, some 140 feet high, and partially settled by property-owning African Americans before it was taken by eminent domain in 1857. Golden Gate Park in San Francisco was principally a giant sand dune prior to design. Forest Park in Portland, Oregon, was created in the wake of the logging of the steep site that triggered landslides. Many existing parks are already located in river floodplains or coastal margins. Fairmount Park in Philadelphia and Mill River Park in Stamford, Connecticut, are riverine examples. Passeio Atlântico in Porto, Portugal, and Stanley Park in Vancouver, British Columbia, are coastal examples.

In parallel, there are also parks constructed in previously natural areas well known to flood that, due to development pressures and the intensification of land use in city centers, are developed anyway (examples include Yanweizhou Park, Jinhua City, People's Republic of China, and Parque La Marjal, Alicante, Spain). These parks, sometimes called floodable parks, manage water and water excesses in lieu of a natural system, but (the logic goes) with the addition of a public amenity (Loggia et al., 2020). The two sites studied in this analysis are both parks constructed relatively recently on land previously used for industrial purposes or transportation infrastructure. Corktown Common in Toronto and the East Side Coastal Resiliency Project in New York City are other postindustrial examples designed for flooding. In commercial real estate terms, these are brownfield sites. This is an important distinction amid the tendency to valorize any double-duty park. Developing natural infrastructure or greenfield areas like wetlands—mangrove forests, marshes, and saltmarshes—removes naturally occurring, biodiverse, self-regulating ecosystems that could be part of a valuable natural protection system. When developing flood protection and park land, one must consider prior land use first and foremost.

Many have discussed the policy advantages of double-duty parks or multifunctional infrastructure; however, the purpose of this study is to determine *how* to design for both park needs and flood mitigation related to extreme weather in the same space. It is simply not sufficient to commit land to open space use and expect it to function as a flood buffer and, conversely, to design flood infrastructure and expect it to function well as a park. It is also not sufficient to design for baseline or normal weather conditions; rather, sites need to be designed for extreme duress according to the risk factors affecting each region and site. That is to say, technique, craft, design, siting, and planning for both desired functions are critical to success.

## TWO NATURAL EXPERIMENTS

After Hurricane Sandy in the Northeast in 2012 and Hurricane Harvey in the South in 2017, the promise of double-duty parks' functional and social coupling was tested. Sites in both the Hudson-Raritan Estuary (Figure 1) and the Galveston Bay Estuary (Figure 2) were severely affected by rainfall, stormwater, storm surge, and coastal flooding. In a future where these events are likely to become more common and/or more extreme, landscape architects and urban designers at one private landscape and planning firm, SWA Group, wanted to find out what worked and what did not in terms of design and planning in these public realm spaces.

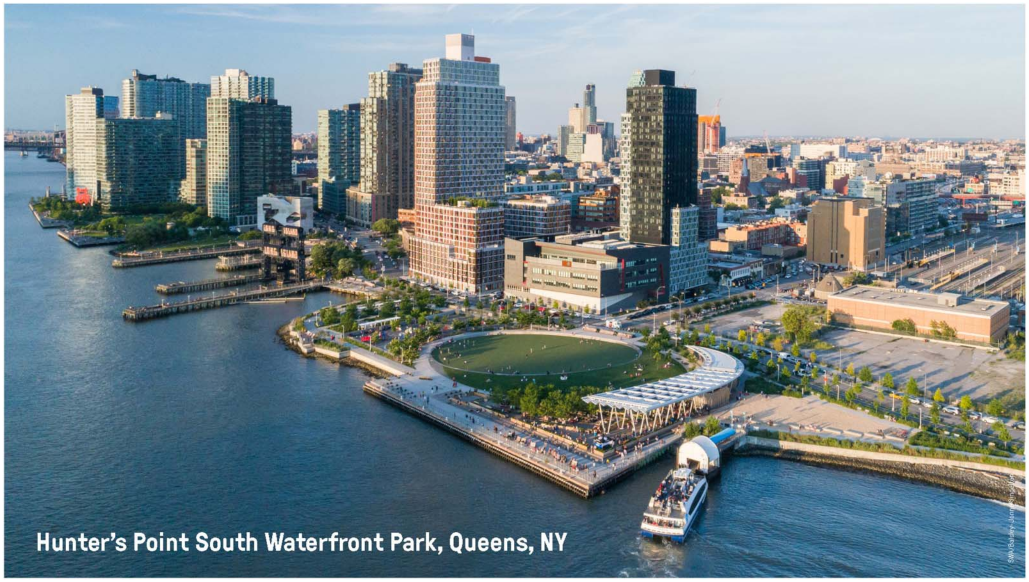


**Figure 1.** SWA Group/Jonnu Singleton.

Against a backdrop of 3 years of post-occupancy analysis on 29 of the firm's built projects, a dedicated practice-based research group within the firm, XL Lab, set out to gather metrics about coastal flooding and stormwater resilience at the site level. The hypothesis was that the two public realm spaces were functioning successfully as parks (with their attendant social, health, and alternative transportation benefits) but also as successful flood infrastructure, even mitigating and managing flooding in extreme events. Anecdotal evidence each design team had collected from contractors, clients, and partners indicated key successes and a few areas for improvement.

Two case studies ensued: one study done in 2018 with the Landscape Architecture Foundation (LAF) and Penn State University researchers on a coastal site—phase one of Hunter's

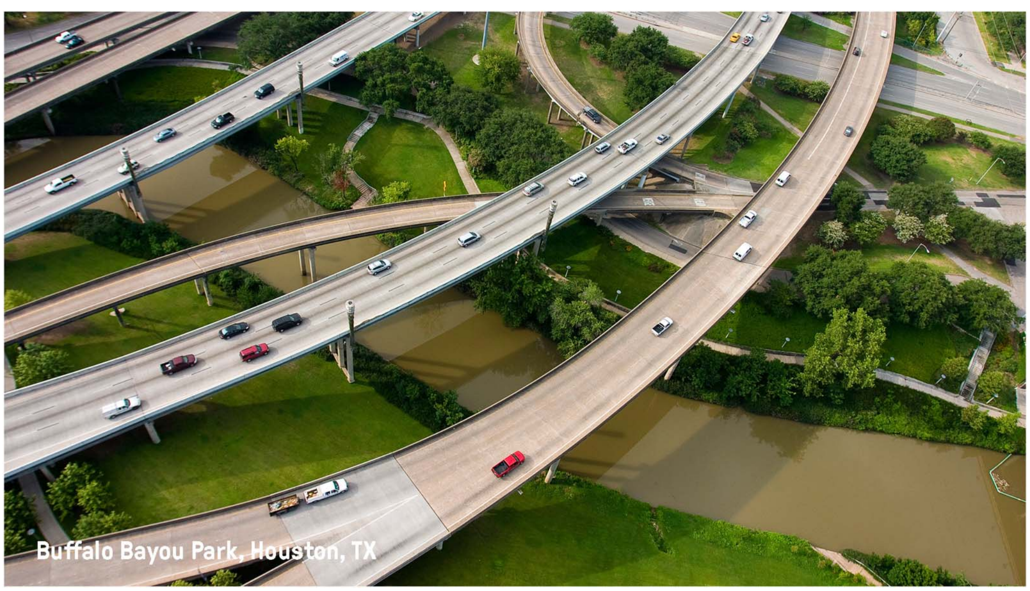


**Figure 2.** SWA Group/William Tatham.

Point South Waterfront Park in New York City (LAF, 2018)—and another study done in 2019 on a riverine site with LAF and University of Texas (UT) at Arlington researchers at Buffalo Bayou Park in Houston, Texas (LAF, 2019). The second case study follows up on a previously completed study of the site that serves as a baseline (LAF, 2013). For both studies, social performance, recreational and health outcomes, and economic and environmental performance, including flood protection, were studied. The brief discussion here will focus more narrowly on each site's performance as flood infrastructure in extreme conditions using findings from the two studies and from XL Lab data.

## MATERIALS AND METHODS

Both sites were evaluated on their capacity for resilience as introduced by Canadian ecologist C. S. Holling, who emphasized designing for "ecological resilience," defined as "the amount of disturbance that can be sustained before a change in system, control and structure occurs" (Holling, 1996, p. 33). The design recommendations below are categorized on the properties of resilience more recently defined by Bruneau et al. (2003, pp. 737–738) for seismic events: robustness, rapidity, redundancy, and resourcefulness.

- Robustness: strength, or the ability of elements, systems, and other units of analysis to withstand a given level of stress or demand without suffering degradation or loss of function.
- Redundancy: the extent to which elements, systems, or other units of analysis exist that are substitutable, i.e., capable of satisfying functional requirements in the event of disruption, degradation, or loss of functionality.
- Resourcefulness: the capacity to identify problems, establish priorities, and mobilize resources when conditions exist that threaten to disrupt some element, system, or other unit of analysis; resourcefulness can be further conceptualized as consisting of the ability to apply material (i.e., monetary, physical, technological, and informational) and human resources to meet established priorities and achieve goals.
- Rapidity: the capacity to meet priorities and achieve goals in a timely manner in order to contain losses and avoid future disruption.

Throughout the analysis, the team was also attentive to larger systems-level capacities for resilience: capacity to resist, capacity to absorb and recover, and capacity to transform and adapt (Hegger et al., 2016).

Methods of investigation included mapping, interviews, site photographs, video, construction document takeoffs, and hydrologic modeling for the first site. For more on the academic team's methods, see the case study methods document (DuRussel & Singh, 2018). For the second site, methods of investigation included mapping, data analysis (aerial images, high-water elevations, and geospatial data sets), interviews, time-series site photographs, an onsite survey of visitors, and construction document takeoffs. For more on that academic team's methods, see the case study methods document (Aman & Yildirim, 2019).

### Hurricane 1, Coastal Site

The first site, Hunter's Point South Waterfront Park, Phase 1, is in a coastal location in the borough of Queens in New York City. In the late 19th century, the area saw heavy industrial use with crisscrossing rail tracks terminating at a tidal strait in New York Harbor, the East River. Later, in the 1970s and after, it was a private tennis club on a hardened bulkhead that turned its back on the waterfront. In 2009, a team led by engineers at the global firm Arup presented design concepts for the first phase of a park. In addition to implementing the client's design principles, landscape architects Thomas Balsley Associates, now SWA/Balsley, along with architects Weiss Manfredi, designed a park intended to "bend and not break" (Dunlap, 2013) in the case of extreme weather. In 2012, as the park was partway through active construction, the design was tested when Hurricane Sandy made landfall on October 29 as a Category 1 hurricane (Figure 3). Six years later, the case study was intended to answer some basic questions about the event: 1) how the design performed as flood infrastructure during and after this event, and 2) what designers could learn about designing for extreme events in coastal settings for use in other projects.

Starting with the first question led to the understanding that the flooding extents encompassed almost the whole park. Looking at historical maps dating prior to industrial development showed the team that the extents of flooding overlapped almost exactly with historical marshland. The floodwaters reached about 4 feet (1.2 meters) high on the construction site (Figure 4). In terms of how the park performed, the team focused on the stormwater management features, water storage capacity, speed of recovery, and the impact to features. The study found that the amount of rainfall that accumulated as runoff was less than one-third of the total. Some of this water was absorbed by features like the rock-filled gabions sunk into a filter strip along the western edge of the park in order to intercept, absorb, and slow drainage to the sewer system. In terms of water storage capacity to slow drainage, the study found that the central oval lawn provided over 550,000 gallons of temporary water storage. For comparison, that equates to detaining 85% of the water contained in an Olympic-sized swimming pool. The speed of recovery on site was fast; in under five days, all water was drained from the site. The impact to already constructed features was found to be minimal. The pavilion canopy, decking, paving, bulkhead, and riprap withstood the storm with no significant damage (Figures 5, 6).

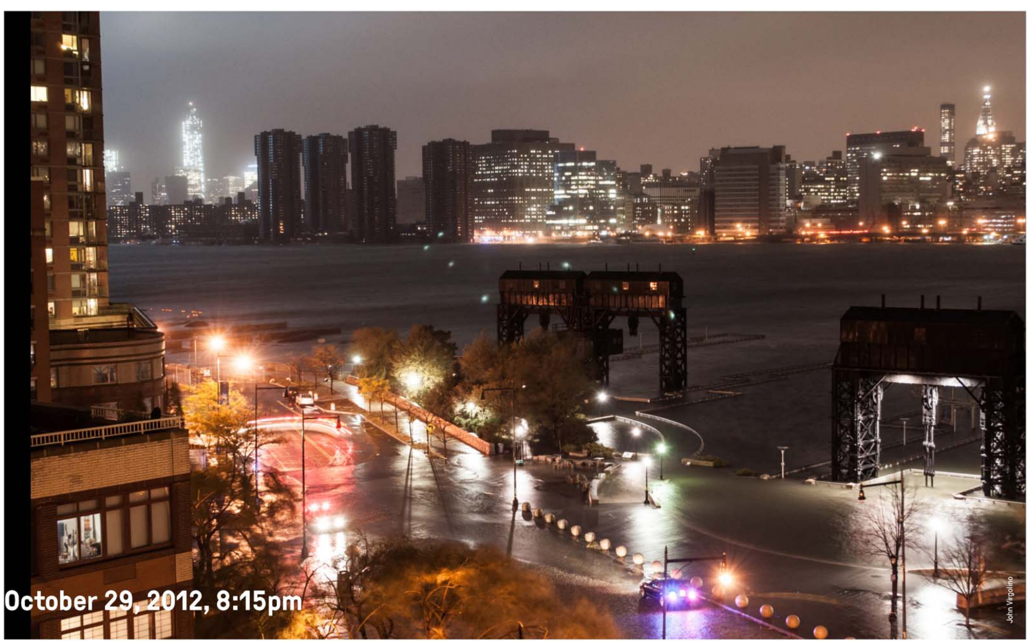


**Figure 3.** John Virgolino.


**Figure 4.** Weiss Manfredi.

XL Lab was able to understand many things about the hurricane event 6 years prior but was unable to obtain detailed site information, notably the force with which floodwaters entered the site and the wind speed on site during the event. The team was also unable to obtain any documentation of the storm's damage to soil and trees. There are still many challenges in obtaining site-level or even neighborhood-level data during and directly after hurricane events on metrics like local water flow speed, wind speed, water height, and drainage speed.

#### Hurricane 2, Riverine Site

The second study site, on a riverine SWA-designed park near Houston, Texas, is a 2.3 mile (3.7 kilometer) linear park along an urban river that is designed to be floodable. Buffalo

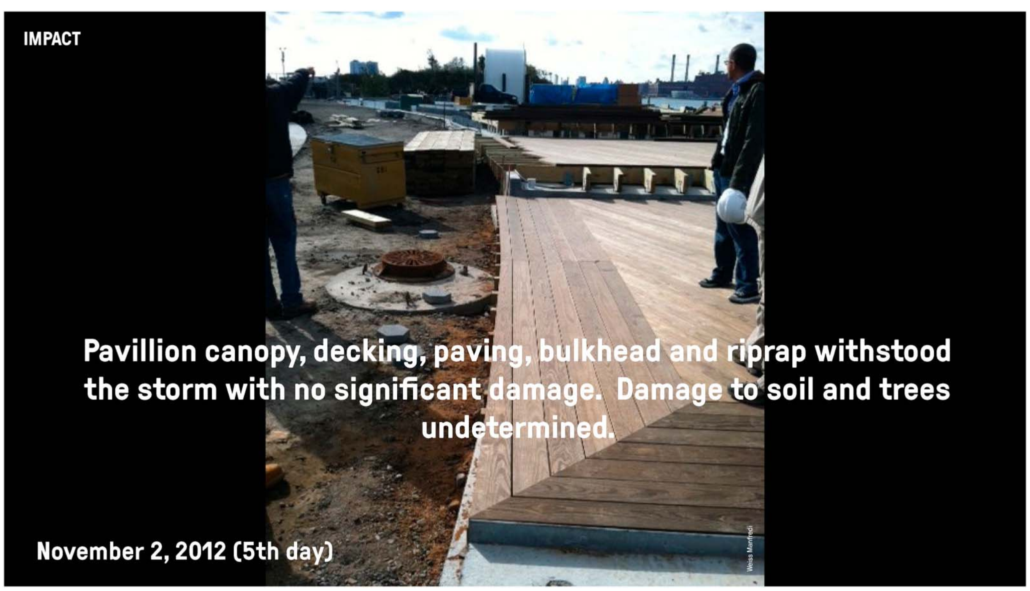


**Figure 5.** Weiss Manfredi.

**Figure 6.** Weiss Manfredi.

Bayou Park lies just west of downtown Houston, on either side of Buffalo Bayou and between two busy arterials, Memorial Drive and Allen Parkway. The park is made up of several sections designed at different times starting in 2015 and continuing up until the current moment with the in-progress East Section (Olson & Theis, 2017). Funded through a public–private partnership model, the project kicked off with a generous private foundation gift, with Harris County Flood Control District (a state partner of the USACE) also contributing, and Buffalo Bayou Partnership, who manages the park, raising the remaining funds through a capital campaign. Illustrating the community's broad support for the project, more than 850 local foundations, corporate donors, and individual donors contributed to making the park a reality. Historically, the river, although in downtown Houston, was effectively ignored until Terry Hershey, a local activist, drew attention to Houston's bayous in the 1960s. Now the river at the center of the park is an attraction, as well as accessible; approximately 44,000 households can access the park within a 10-minute walk and approximately half a million people within a 30-minute bike ride.

Buffalo Bayou Park has undergone many flood events, but it had its major test when Hurricane Harvey made landfall on August 25, 2017, as a Category 4 hurricane (Figure 7). (For reference, Hurricane Katrina was a Category 3 hurricane at landfall in New Orleans in 2005). Major flooding occurred after two large reservoirs upstream were released on August 28. When researchers conducted their case study in 2019, they obtained aerial images and other data that allowed a better sense of basic information, like the extents of the flooding over time (Figures 7, 8), than was available during the study of the Hunter's Point South Waterfront Park. A record 39 feet (almost 12 meters) of flood elevation was recorded at Shepherd Drive Bridge in Houston.

To measure park performance during the hurricane event, XL Lab was interested in identifying what withstood damage and what failed, how much floodable development saved in costs over nonfloodable development, and speed of recovery. Unlike the coastal study in New York, it was inherently difficult to measure success in one section of the channel or park because upstream flooding and channel design affected everything downstream. The

**Figure 7.** Geoffrey Lyon.

features that withstood flooding and high water speeds were custom stair handrails, guardrails, and light poles that were designed with higher strength material and thicknesses (Figures 9, 10). The UT Arlington team found that these high-strength features led to an avoidance of an estimated US$2 million in damages (Aman & Yildirim, 2019). A number of the less expensive 2:1 vegetated slopes failed, but the more expensive coir lifts had no

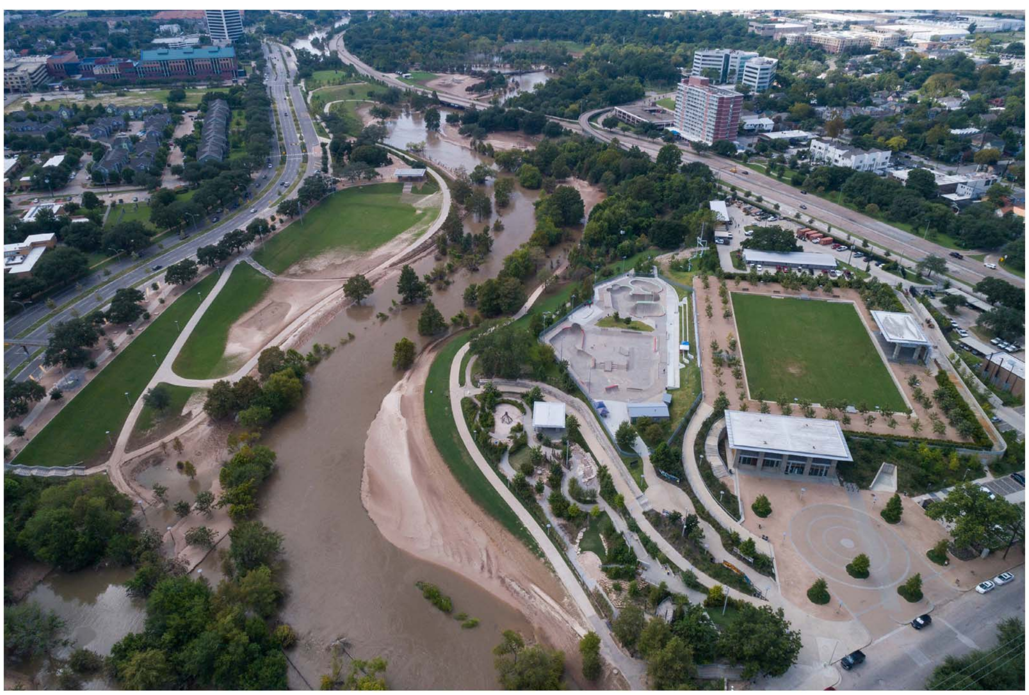

**Figure 8.** SWA Group/Jonnu Singleton.

**Figure 9.** SWA Group/Jonnu Singleton.

slope failures and avoided an estimated US$730,000 in repair costs, according to the UT Arlington team's findings. With repair costs, the price of the two bank stabilization techniques was almost equal after one flood event. Another savings related to the floodable park design was the reduction in lawn area and turf maintenance hours, which saves an estimated US$52,000 annually. Lastly, the speed of recovery and the speed of drainage were determined by aerial photos at 1 week, 2 weeks, and 3 months after the hurricane made landfall. Once the floodwaters receded, people quickly returned to using the park, but the 80 million pounds (36 million kilos) of deposited silt took weeks to remove (Figure 11). This

**Figure 10.** SWA Group/Jonnu Singleton.


**Figure 11.** SWA Group/Maribel Amador.

was a relatively speedy cleanup due to an existing dedicated fund for maintenance. However, the weeks spent underwater, and/or under silt, deprived many of the park's trees of oxygen. In total, 400 trees died and had to be replaced.

**RESULTS**

Although Hunter's Point South Waterfront Park has yet to be tested in its fully constructed form, data on storm impact and recovery at the substantially built site offered insight into the design decisions that contributed to the park's resilience post-hurricane. At Buffalo Bayou Park, both the team's data analysis and the UT Arlington team's work highlighted design decisions that contributed to its resilience post-hurricane, though future storm outcomes may change in this section of the river as upstream sections are altered by future development.

In the following list of takeaways, these design guidelines are generalized to apply to a wide variety of riverine and coastal sites. There are many ways to achieve these ends and fit them to the specificity of each site, regional hazards, weather patterns, and frequency or volume of users.

Takeaways for use on other coastal projects:

1. Robustness: Raise a large portion of the site higher than the 100- or 200-year flood level.
2. Robustness: Use materials that bend but do not break, or where possible, employ over-engineered or overbuilt elements.
3. Rapidity: Exit most of the surface water, which is unpolluted, to the river, not the storm sewer system.
4. Rapidity: Make a moderately easy entry for water to the site, and there will be less damage to site elements.
5. Rapidity: A quick recovery decreases costs.
6. Redundancy: More softscape area slows and absorbs more water, as well as slowing drainage to the sewer. Make other temporary storage areas for water to drain to.
7. Resourcefulness: Everything gets wet and salty. Make plantings salt tolerant and low soil-oxygen tolerant.

Takeaways for use on other river projects:

1. Robustness: Heftier light poles, railings, trash cans, and furnishings anchored below ground withstood impacts. Deep pilings for bridges were necessary for soft soil.
2. Robustness: High clearance bridges stayed above flood levels. Low clearance bridges became strainers and caught debris, which created extra pressure.
3. Robustness: Low-lying areas and former oxbows took the biggest hits, were difficult to maintain, and needed to be the most durable.
4. Rapidity: Sloped surfaces of walks and walls and the rounded corners of elements caught less debris and therefore created less drag underwater.
5. Redundancy: Flood benches designed to act as speed humps where fast moving floodwater can spread out and drop silt and debris worked. However, slowing water meant a lot of silt deposition.
6. Redundancy: Redundancy in design features was important. For example, upper paths could be used quickly, while lower ones were cleared later.

## DISCUSSION AND CONCLUSIONS

Today, landscape architects aim to build double-duty projects that perform well as the social and recreational spaces we know as parks and as sustainable infrastructure that not only withstands and is resilient after extreme pressures like flooding, high winds, and salt inundation, but contributes positively to larger urban social and environmental systems and anticipates climate change–influenced shocks and increased risks. Ultimately, these two studies reveal that public spaces can be successfully designed as flood infrastructure if careful design and management tactics are employed.

The social and functional coupling inherent to double-duty parks also serves a valuable educational purpose for the visiting public. At Hunter's Point South Waterfront Park, the familiar park landmarks along the waterfront functioned as high-water gauges for those living in the series of high-rise towers that overlook the park. Residents could tell that this was a significant event from their personal experience. At Buffalo Bayou, the longer cleanup time for the silt deposition, combined with early park usage after the storm, served as potent evidence and a reminder of the impact, power, and cost of these extreme weather events (Yildrim et al., 2021). Not only are these parks performing functions previously handled solely by civil engineers, they also introduce a way for communities to see, interact with, interpret, and understand the possible effects of climate change firsthand. This may be the greatest benefit of implementing hybrid infrastructure-park projects, because resilience relies, ultimately, on social and political will that prioritizes and funds well-constructed, well-designed spaces.

## REFERENCES


Aman, A., & Yildirim, Y. (2019). Buffalo Bayou Park methods. *Landscape Architecture Foundation*. https://www.landscapeperformance.org/sites/default/files/Buffalo-Bayou-Park-Methods_1.pdf

Bruneau, M., Chang, S. E., Eguchi, R. T., Lee, G. C., O'Rourke, T. D., Reinhorn, A. M., Shinozuka, M., Tierney, K., Wallace, W. A., & von Winterfeldt, D. (2003). A framework to quantitatively assess and enhance the seismic resilience of communities. *Earthquake Spectra*, *19*(4), 733–752. https://doi.org/10.1193/1.1623497

Dunlap, D. W. (2013, September 4). A Queens park opens, already a storm survivor. *The New York Times*. https://www.nytimes.com/2013/09/05/nyregion/a-queens-park-opens-already-a-storm-survivor.html

DuRussel, L., & Singh, A. (2018). *Hunter's Point South Waterfront Park methods. Landscape Architecture Foundation*. https://www.landscapeperformance.org/sites/default/files/Hunter%27s%20Point%20South%20Methods_0.pdf

Feagin, R. A., Bridges, T. S., Bledsoe, B., Losos, E., Ferreira, S., Corwin, E., Lodder, Q., Beck, M. W., Reguero, B., Sutton-Grier, A., Figlus, J., Palmer, R., Nelson, D. R., Smith, C., Olander, L., Silliman, B., Pietersen, H., Costanza, R., Gittman, R. K., ... Guidry, T. (2021). Infrastructure investment must incorporate Nature's lessons in a rapidly changing world. *One Earth*, *4*(10), 1361–1364. https://doi.org/10.1016/j.oneear.2021.10.003

Hegger, D., Driessen, P., Wiering, M., van Rijswick, H., Kundzewicz, Z., Matczak, P., Crabbé, A., Raadgever, G., Bakker, M., Priest, S., Larrue, C., & Ek, K. (2016). Toward more flood resilience: Is a diversification of flood risk management strategies the way forward? *Ecology and Society*, *21*(4), Article 52. https://doi.org/10.5751/ES-08854-210452

Holling, C. S. (1996). Engineering resilience versus ecological resilience. In P. Schulze (Ed.), *Engineering within ecological constraints* (pp. 31–44). The National Academies Press. https://doi.org/10.17226/4919

Kuang, D., & Liao, K.-H. (2020). Learning from floods: Linking flood experience and flood resilience. *Journal of Environmental Management*, *271*, Article 111025. https://doi.org/10.1016/j.jenvman.2020.111025, PubMed: 32778305

Landscape Architecture Foundation. (2019, August 9). *Buffalo Bayou Park | Landscape Performance Series. Landscape Architecture Foundation*. https://www.landscapeperformance.org/case-study-briefs/buffalo-bayou-park

Landscape Architecture Foundation. (2013, September 17). *Buffalo Bayou Promenade | Landscape Performance Series*. https://www.landscapeperformance.org/case-study-briefs/buffalo-bayou-promenade

Landscape Architecture Foundation. (2018, August 10). *Hunter's Point South Waterfront Park, Phase 1 | Landscape Performance Series*. https://www.landscapeperformance.org/case-study-briefs/hunters-point-south

Le, T. Q., Devisch, O., & Trinh, T. A. (2019). Flood-resilient urban parks: Toward a framework. *Area*, *51*(4), 804–815. https://doi.org/10.1111/area.12543

Loggia, G., Puleo, V., & Freni, G. (2020). Floodability: A new paradigm for designing urban drainage and achieving sustainable urban growth. *Water Resources Management*, *34*, 3411–3424. https://doi.org/10.1007/s11269-020-02620-6

Matos Silva, M., & Costa, J. P. (2016). Flood adaptation measures applicable in the design of urban public spaces: Proposal for a conceptual framework. *Water*, *8*(7), Article 7. https://doi.org/10.3390/w8070284

Olson, A., & Theis, D. (2017). *From rendering to reality: The story of Buffalo Bayou Park*. Buffalo Bayou Partnership.

Reynaud, A., Lanzanova, D., Liquete, C., & Grizzetti, B. (2017). Going green? Ex-post valuation of a multipurpose water infrastructure in Northern Italy. *Ecosystem Services*, *27*(Part A), 70–81. https://doi.org/10.1016/j.ecoser.2017.07.015, PubMed: 29034161

Silva, M. M., & Costa, J. P. (2018). Urban floods and climate change adaptation: The potential of public space design when accommodating natural processes. *Water*, *10*(2), Article 2. https://doi.org/10.3390/w10020180

Syahirani, T. N. T., & Ellisa, E. (2021). Public space as water infrastructure strategy in achieving runoff flood resilience on a neighborhood scale. *IOP Conference Series: Earth and Environmental Science*, *716*(1), Article 012079. https://doi.org/10.1088/1755-1315/716/1/012079

Yildrim, Y., Keshavarzi, G., & Aman, A. R. (2021). Can urban parks help with disaster risk reduction through educational awareness? A case study of Hurricane Harvey. *International Journal of Disaster Risk Reduction*, *61*, Article 102377. https://doi.org/10.1016/j.ijdrr.2021.102377