

Buffalo Bayou Park Methods

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Overview

Buffalo Bayou Park is an urban green space located upstream of downtown Houston, Texas, along Buffalo Bayou, the principal drainage system for much of the city. Tested by three major floods since its opening – including Hurricane Harvey, which dropped 27 trillion gallons of water on metropolitan Houston – Buffalo Bayou Park is a precedent for resilient open-space design, planning, and operations in climate-sensitive and flood-prone coastal areas in an age of accelerated climate change with devastating potential impacts. The design of the park sought to mitigate seasonal and catastrophic flooding events while also restoring ecologies and systems, simplify and streamline maintenance procedures, improve the health and well-being of park users, and to catalyze economic revitalization in the areas adjacent to the park. The research outline below shows that since the park’s opening, it has performed as designed relative to flood events, restored ecologies and promoted pollinator habitat, improved the health and well-being of park users and educated the public on flood protection, and has catalyzed development and increased property values in the areas adjacent to the park.

Environmental Benefits

1. **Withstood significant flooding and avoided an estimated \$2 million in damages from Hurricane Harvey with custom-designed site fixtures and furnishings.**

Methods:

Site fixtures and furnishings within Buffalo Bayou Park were custom-designed to withstand submersion during flood events and the impact of floating debris. Trail light poles, stair handrails and guardrails were designed with higher material strength and thickness, which led to higher upfront costs. This customization was necessitated by the frequency of flood events the park experiences (and will continue to experience) each year with the goal of limiting the costs in damages after each event. It may be assumed that if off-the-shelf products had been used, they would not have withstood the effects of Harvey and would have needed to be replaced.

Calculations:

The upfront material costs for each of these items was compared to typical off-the-shelf costs for similar fixtures and furnishings without customization. Locations, quantities, and linear footages of these items were extracted from the construction drawings, and the product costs per item/linear foot were provided by the landscape architect.

Using the high water level elevations during Hurricane Harvey (provided by the Harris County Flood Control District) at Shepherd Dr. (elevation 41.1) and Sabine St. (39.9) – the two borders of the park – high water level surface elevations along the entire corridor were extrapolated. The average of these water surface elevations, +/- 40.5, was used for the entire park. Because each light pole is 11'-0" tall from finish grade (FG) to top of fixture, three categories of impact were created for this analysis:

Total Trail Light Poles: 486

Total Submersion: Finish Grade (FG) +29 and below: 283 fixtures

$$283/486 = .582 * 100 = \mathbf{58\%}$$

Partial Submersion: Finish Grade (FG) +30 to +40: 122 fixtures

$$122/486 = .251 * 100 = \mathbf{25\%}$$

No Submersion: Finish Grade (FG) +40 and above: 81 fixtures (17%)

$$81/486 = .167 * 100 = \mathbf{17\%}$$

From this extrapolation, it was determined that approximately 83% of the light poles and fixtures (shown as an example in the calculations above) and approximately 95% of the stairs, retaining walls, and associated handrails, and guardrails were submerged and/or subject to floating debris. In order to estimate the potential costs in damages for these items should off-the-shelf items have been implemented instead, we applied this percentage to determine replacement costs.

Custom Concrete Light Pole and Fixture

Quantity: 486

For reference/comparison: custom fixtures installed on site (pole & fixture): \$8,500 each

$$486 * \$8,500 = \$4,131,000$$

Off-the-shelf fixture (pole & fixture): \$4,000 each

$$486 * \$4,000 = \$1,944,000$$

$$\$1,944,000 * 0.83 = \mathbf{\$1,613,520 \text{ avoided}}$$

Handrails

Quantity: 1,534 lf

For reference/comparison: custom handrails installed on site: \$200/lf

$$1,534 * \$200 = \$306,800$$

Off-the-shelf handrails: \$115/lf

$$1,534 * \$115 = \$176,410$$

$$\$176,410 * .95 = \mathbf{\$167,590 \text{ avoided}}$$

Guardrails

Quantity: 1,083 lf

For reference/comparison: custom guardrails installed on site: \$350/lf

$$1,083 * \$350 = \$379,050$$

Off-the-shelf guardrails: \$200/lf

$$1,083 * \$200 = \$216,600$$

$$\$216,600 * .95 = \mathbf{\$205,770 \text{ avoided}}$$

$$\$1,613,520 + \$167,590 + \$205,770 = \mathbf{\$1,986,880 \text{ avoided}}$$

Initial Cost Comparison for Custom v. Off-the-shelf:

Custom: \$4,131,000 + \$306,800 + \$379,050 = \$4,816,850

Off-the-shelf: \$1,944,000 + \$176,410 + \$216,600 = \$2,337,010

After one flood event (Hurricane Harvey):

Custom: \$4,816,850 (initial) + \$0 repair/replacement = \$4,816,850

Off-the-shelf: \$2,337,010 (initial) + \$1,986,880 repair/replacement = \$4,323,890

Note: These calculations take into consideration one flood event only (Hurricane Harvey). While the upfront costs were higher for these custom fixtures and furnishings, the avoided costs in damages, replacement, and repair has grown and will continue to grow with each flood event, given that the site is likely to withstand multiple flood events expected each year.

Sources:

Construction documents and secondary data provided by the landscape architect, SWA.

Limitations:

The exact number of light fixtures and linear footage of handrails and guardrails that would have been replaced as a result of Hurricane Harvey was estimated based on water level elevations relative to item locations and likelihood of damage. The percentage used for this calculation is therefore an estimation.

Labor and Installation costs were not included in this analysis.

2. Avoided an estimated \$735,900 in flood repair costs from Hurricane Harvey through installation of coir lifts.

Methods:

A series of riparian bank stabilization techniques were considered during the design phase of Buffalo Bayou Park in order to control for bank erosion from fluctuating water levels throughout the course of each flood season. Due to the prohibitive cost of installing more effective stabilization techniques, a majority of the bayou banks were stabilized with vegetation at a 2:1 slope where wetland species would occupy the portion of the bank that would occasionally submerge, with a native grass mix above. This decision suited the project budget as vegetated slope costs were at \$72.50/lf. The downside to this technique is that the potential for slope failure was much greater during flood events. After Hurricane Harvey, a number of these slopes failed and were in need of repair. It was determined that the repair cost for vegetated slope failures was \$748.50/lf (ref. Figures 26 and 27 under Cost Comparison for more details).

However, a few select locations along the bayou were stabilized with coir lifts (a very effective stabilization method) due to their high potential for slope failure during major flooding events. Coir lift costs were at \$864.80/lf. The coir lifts performed extremely well during Hurricane Harvey and had no failures and therefore no associated repair costs. If these slopes had been constructed as vegetated slopes initially they likely would have failed, which would have resulted in additional repair costs.

Calculations:

Initial cost for coir lifts installation for approximately 900 lf of banks:

$$900 \text{ lf} * \$864.80/\text{lf} = \$778,320$$

Instead:

Initial cost for banks to be stabilized with vegetation:

$$900 \text{ lf} * \$72.50/\text{lf} = \$62,250$$

Repair cost if banks had failed during Hurricane Harvey:

900 lf* \$748.50 lf = \$673,650

Total stabilization and repair cost after Hurricane Harvey: **\$735,900**

This repair cost would continue to increase over time due to repetitive flood events causing additional need for slope repairs without highly effective bank stabilization techniques having been employed. For example, even with one more flood event similar to Hurricane Harvey, this could double the total repair cost to \$1,471,800. As compared to the initial cost for coir lift installation as a highly effective stabilization method, the total investment would have doubled.

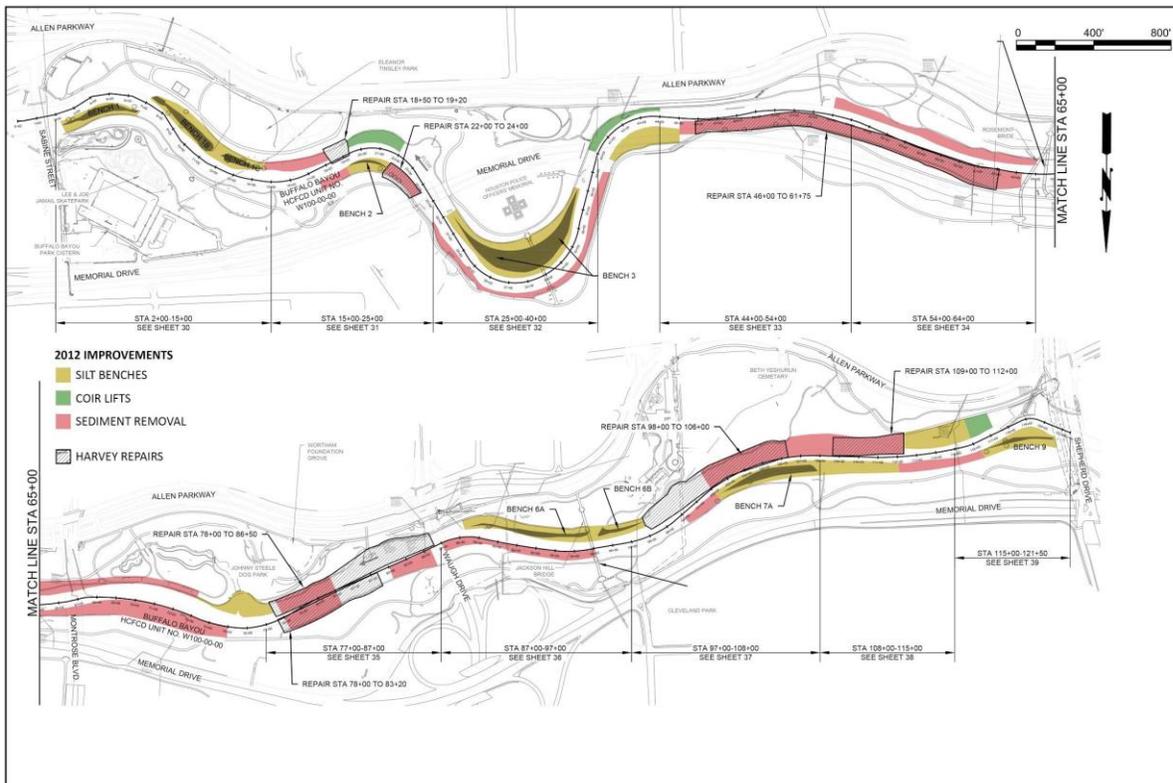


Figure 1: Coir Lift Locations Relative to Repair and Sediment Removal Locations as a Result of Hurricane Harvey (SWA)

Sources:

Stabilization data was provided by the landscape architect, SWA, and the Harris County Flood Control District (HCFCD).

Limitations:

The costs determined for each stabilization technique are for construction costs only as they do not include soft costs, design fees, or contractor overhead.

- 3. **Increases habitat quality within 25% of the park by providing fruit and seed sources for wildlife in 53% of newly-planted native groundcover and shrub species, nectar sources in 63%, and habitat sources in 27%, with 23% of these species designated as having Special Value for native pollinators.**

Methods:

Three planting zones totaling 40 acres (approximately 25% of the park acreage) were analyzed for their habitat benefits, given their species compositions and potential value for habitat. These three zones include Native Woodland, Cultured Woodland, and Open Meadow. The remaining planting zones (Riparian and Turf), the bayou itself, and the trails and hardscape surfaces in the park were excluded from this analysis.

BUFFALO BAYOU LANDSCAPE/HABITAT ZONES			
ZONES	ACREAGE	TOTAL	Figure Ref.
Native Woodland		9.72	
25% Groundcover and Shrubs	2.43		1
75% Meadow	7.29		2
Cultured Woodland		14.67	
100% Meadow	14.67		2
Open Meadows		15.20	
100% Open Meadow	15.20		3
TOTAL		39.59	acres

Figure 2: Planting Zone Table

The Native Woodland planting zone comprises 25% groundcover and shrubs, and 75% meadow grasses and wildflowers. The Cultured Woodland planting zone comprises of 100% meadow grasses and wildflowers. The same meadow grass and wildflower seed mix was planted in both of these zones. The Open Meadow planting zone is comprised of 100% meadow grasses and wildflowers that uses a different seed mix.

The groundcover and shrub composition within the Native Woodland planting zone was analyzed first (Figure 3). Each species was cross referenced with The Xerces Society for Invertebrate Conservation Pollinator Conservation Program Special Collections Lists to determine whether or not those species had been assigned Special Value for pollinators. The Xerces Society defines Special Value as being recognized by pollination ecologists for attracting large numbers of native bees, bumble bees, honey bees, butterflies, and moths. Each species was then also cross referenced with the Lady Bird Johnson Wildflower Center plant databases to determine the habitat sources provided for wildlife including fruit and seeds, nectar, and nesting habitat. Finally, the total area of species

within each of these habitat benefit categories was calculated as a percentage of the total groundcover and shrub area.

The meadow grass and wildflower mix within the Native and Cultured Woodland planting zones was analyzed next (Figure 4). Similar to above, each species was cross referenced with Xerces Society for Invertebrate Conservation Pollinator Conservation Program Special Collections Lists to determine whether or not those species had been assigned Special Value for pollinators. The total area of species having been assigned Special Value was then calculated as a percentage of the total meadow grass and wildflower mix area.

Finally, the meadow grass and wildflower mix within the Open Meadow planting zone was analyzed in the same manner as above (Figure 5).

As a note, given that the park's primary goal was to function properly as a flood-based public landscape, plant species and seed mixes that supported this function (the criteria being their ability to stabilize the banks of the bayou to prevent slope failure and their ability to withstand periodic inundation) and could withstand other climatic factors were given priority in certain areas of the park over pollinator and other habitat generating species.

Calculations:

For the groundcover and shrub composition analysis, the square footage of each species had to be determined first. The landscape architect provided the species mix allocation per acre (%) and the total acreage for the Native Woodland planting zone. Each species square footage was calculated by multiplying the species mix allocation per acre (%) by the total square footage of the groundcover and shrub composition (25% of the Native Woodland acreage). Each species was then cross referenced with The Xerces Society for Invertebrate Conservation Pollinator Conservation Program Special Collections Lists and the Lady Bird Johnson Wildflower Center plant databases to determine habitat benefits, as discussed above under *Methods*. The total area of species within each of these habitat benefit categories was calculated as a percentage of the total groundcover and shrub area.

GROUNDCOVER AND SHRUBS	SF	Acres
Native Woodland GC and Shrubs (25% of SF)		

Total Site Acreage	423,209	9.72
Native Groundcover and Shrubs	105,802	2.43 (25% of total acreage)

Common Name	% Mix (Species)	SF	Xerces Society for Invertebrate Conservation Pollinator Program			Lady Bird Johnson Wildflower Center			
			Pollinator	Notes:	SF Pollinator	Attracts Wildlife	Attracts Butterflies/Insects	Larval Host	
						LBJWC Fruit/Seed Source	LBJWC Nectar Source	LBJWC Habitat/Host	
American Beautyberry	7%	7,406				7,406			
Arrowhead Viburnum	6%	6,348	Y	Native Bees/Butterfly	6,348			6,348	
Buttonbush	6%	6,348	Y	Native/Bumble/Honey Bees/Butterfly	6,348			6,348	
Coralbean	5%	5,290					5,290		
Gulf Coast Penstemon	5%	5,290	Y	Native Bees	5,290			5,290	
Horseherb	5%	5,290					5,290		
Inland Sea Oats	15%	15,870				15,870		15,870	
Maple-leaf Viburnum	6%	6,348	Y	Butterfly	6,348			6,348	
Partridgeberry	5%	5,290				5,290			
Scarlet Sage	6%	6,348					6,348		
Southern Woodfern	3%	3,174					3,174		
Texas Lantana	6%	6,348					6,348		
Turk's Cap	15%	15,870				15,870		15,870	
Virginia Sweetspire	5%	5,290					5,290		
Walter's Viburnum	5%	5,290				5,290			
TOTAL	100%	105,802							
TOTAL POLLINATOR					24,335	56,075	66,655	28,567	SF
% POLLINATOR/BENEFIT					23	53	63	27	%

Figure 3: Calculation Spreadsheet for Species Habitat Benefits - Native Woodland Groundcover and Shrubs

Example:

American Beautyberry (7% Species Mix)

$$105,802 \text{ sf} \cdot 0.07 = 7,406 \text{ sf}$$

Fruit/Seed Source? Y

The total square footage for all species within the Fruit/Seed Source habitat benefit category was then divided by the total groundcover and shrub square footage.

$$(56,075 \text{ sf} / 105,802 \text{ sf}) \cdot 100 = \mathbf{53\%}$$

For the meadow grass and wildflower mix analysis within the Native and Cultured Woodland planting zones and the Open Meadow planting zone, the same process was used as above. Each species was cross referenced with The Xerces Society for Invertebrate Conservation Pollinator Conservation Program Special Collections Lists only due to the potential habitat benefits being mostly pollinator-driven.

GRASS/WILDFLOWER MIXES	SF	Acres
Native Woodland Grasses (75% of SF)	317,552	7.29
Cultured Woodland Grasses (100% of SF)	639,025	14.67
Grass/Wildflower Mix	956,577	21.96

GRASS/WILDFLOWER MIX	Xerces Society for Invertebrate Conservation Pollinator Program				
Common Name	Live Seeds/SF	% of Total	Value	Notes:	SF Pollinator
Plains Coreopsis	11.61	111,059			
Black-eyed Susan	11.23	107,424			
Sideoats Grama	8.38	80,161	Y	Nesting/Structure	80,161
Plains Bristlegrass	7.36	70,404			
Clasping Coneflower	7.05	67,439			
Prairie Agalinis	5.53	52,899			
Purpletop	4.61	44,098			
Little Bluestem	15.99	152,957	Y	Nesting/Structure	152,957
Scarlet Sage	4.31	41,228			
Prairie Wildrye	3.99	38,167			
Purple Three Awn	3.54	33,863	Y	Nesting/Structure	33,863
Golden-Wave	3.49	33,385			
Virginia Wildrye	3.25	31,089			
Inland Sea oats	3.12	29,845			
Winecup, Annual	2.33	22,288	Y	Native Bees	22,288
Purple Coneflower	1.04	9,948	Y	Native Bees	9,948
Cutleaf Daisy	1.04	9,948	Y	Conservation Bio Control	9,948
Drummond Phlox	0.71	6,792			
Butterfly Weed	0.55	5,261	Y	Native Bees, Bumble Bees, Honey Bees	
Purple Coneflower	0.48	4,592	Y	Native Bees	4,592
Winecup	0.35	3,348	Y	Native Bees	3,348
Pigeonberry	0.04	383			
TOTAL	100.00	956,577			
TOTAL BENEFITS					317,105 SF
% SPECIAL VALUE/BENEFIT					33%

Figure 4: Calculation Spreadsheet for Species Habitat Benefits - Native and Cultured Woodland Meadows

MEADOW/WILDFLOWER MIXES	SF	Acres
Open Meadows (100% of SF)	661,800	15.2
Meadow Mix	661,800	15.2

MEADOW MIX	Xerces Society for Invertebrate Conservation Pollinator Program				
Common Name	Live Seeds/SF	SF	Value	Notes:	SF Pollinator
Sand Dropseed	11.83	78,291	Y	Nesting/Structure	78,291
Plains Coreopsis	5.60	37,061			
Clasping Coneflower	5.51	36,465			
Prairie Agalinis	5.33	35,274			
Purple Three Awn	5.30	35,075	Y	Nesting/Structure	35,075
Sand Lovegrass	4.21	27,862	Y	Nesting/Structure	27,862
Little Bluestem	20.02	132,492	Y	Nesting/Structure	132,492
Black-eyed Susan	4.81	31,833			
Blue Grama	4.57	30,244			
Indian Blanket	4.06	26,869	Y	Native Bees, Bumble Bees	26,869
Lemon Mint	2.83	18,729	Y	Native Bees, Bumble Bees	18,729
Mexican Hat Red	2.72	18,001	Y	Native Bees	18,001
Scarlet Sage	2.67	17,670			
Buffalograss	2.33	15,420			
Purpletop	2.17	14,361			
Prairie Coneflower	2.05	13,567	Y	Native Bees	13,567
Golden-Wave	1.35	8,934			
Gulf Coast Muhly	1.20	7,942			
Curly Mesquite	1.14	7,545			
Texas Cupgrass	1.11	7,346			
Sideoats Grama	1.01	6,684	Y	Nesting/Structure	6,684
Bush Sunflower	0.95	6,287			
Virginia Wildrye	0.88	5,824			
Prairie Wildrye	0.87	5,758			
Purple Coneflower	0.79	5,228	Y	Native Bees	5,228
Lanceleaf Coreopsis	0.72	4,765	Y	Native Bees, Conservation Bio Control	4,765
Drummond Phlox	0.68	4,500			
Texas Bluebonnet	0.61	4,037	Y	Native Bees, Bumble Bees	4,037
Pink Evening Primrose	0.49	3,243	Y	Native Bees	3,243
Winecup	0.49	3,243	Y	Native Bees	3,243
Rattlesnake Master	0.44	2,912	Y	Native Bees, Conservation Bio Control	2,912
Huisache Daisy	0.34	2,250			
Green Sprangletop	0.24	1,588			
Purple Prairie Clover	0.19	1,257	Y	Native Bees, Bumble Bees, Honey Bees	1,257
Cutleaf Daisy	0.18	1,191	Y	Conservation Bio Control	1,191
Texas Yellow Star	0.15	993			
Gayfeather	0.09	596	Y	Native Bees	596
American Basketflower	0.07	463	Y	Native Bees	463
TOTAL	100.00	661,800			
TOTAL BENEFITS					384,506 SF
% SPECIAL VALUE/BENEFIT					58%

Figure 5: Calculation Spreadsheet for Species Habitat Benefits - Open Meadows

Sources:

Native groundcover and shrub species lists and breakdowns were provided by the landscape architect, SWA.

Native grass and wildflower meadow species lists and breakdowns were provided by the Katy Prairie Conservancy

"Plant Lists & Collections." Lady Bird Johnson Wildflower Center - The University of Texas at Austin. Accessed May 18, 2019. <https://www.wildflower.org/collections/>.

"Pollinator Conservation Program." The Xerces Society for Invertebrate Conservation. Accessed May 18, 2019. <https://xerces.org/pollinator-conservation/>.

Limitations:

The plant species and breakdowns used for these calculations were based off of the original construction documents provided by the landscape architect. These calculations do not account for changes in the field during construction or ongoing maintenance, replacement, or repair.

The meadow seed mixes were designed through a series of iterations and were also altered before seeding due to species availability and other issues. The seed mixes used in this analysis reflect the original iteration. In addition, the Native and Cultured Woodland meadow mixes were designed to turnover with more shade tolerant species as the tree canopies grew in over time. The species composition that exists today may promote varied habitat results from this analysis.

Two of the three planting zones analyzed (Native Woodland and Cultured Woodland) also contain a large quantity and variety of tree species that also provide habitat value. These trees were not taken into account for this analysis.

4. Sequesters 9.19 tons of atmospheric carbon and intercepts approximately 84,000 gallons of stormwater runoff annually in approximately 9,800 newly-planted trees.

Methods:

i-Tree Eco v6 is a software application within a suite of tools that utilizes data to estimate ecosystem services and structural characteristics of rural and urban forests. The application provides sampling and data collection protocols, automated processing, and final reports illustrating carbon sequestration in pounds, carbon storage in pounds, and avoided runoff in cubic feet.

The landscape architect provided tree planting data for the park in five planting zones, each with defined species mix percentages per acre. The five zones include: Native Woodland, Cultured Woodland, Riparian Bayou Edge, Garden Areas, and Specimen

Trees. Two zones, Native Woodland and Cultured Woodland, were used for this analysis as they comprise a majority of the number of trees on site and offer the most significant sequestration benefits. The breakdown for each zone was calculated for each species by multiplying the total number of trees specified per acre by the species mix percentage, which was then multiplied by the size mix percentage. The species and DBH (diameter at breast height) for each individual tree (the result of this breakdown) were then entered into i-Tree.

For example, the landscape architect noted that the canopy trees within the Native Woodland zone were to be planted at 300 trees/acre. Sweetgum trees were to represent 11% of this total. Additionally, 8% of sweetgums were to be 65 gallon-sized trees.

$$300 * .11 * .08 = 2.64 \text{ 65-gallon sweetgum trees}$$

This calculation was then repeated for each species and for each species size in order to generate a full breakdown per acre per zone. As a note, the research team had to convert gallons to DBH in order to complete the correct input for i-Tree using the following conversions provided by the landscape architect:

$$65 \text{ gal} = 3" \text{ caliper/DBH}, 30 \text{ gal} = 2.5" \text{ caliper/DBH}, 15 \text{ gal} = 1.5" \text{ caliper/DBH}, 5 \text{ gal} = 1" \text{ caliper/DBH}, 1 \text{ gal} = 0.5" \text{ caliper}$$

Calculations:

i-Tree's database assigns values for each tree species and size types. It uses a calculation to determine CO2 sequestered per tree (kg), and avoided runoff is estimated based on local weather data from the nearest weather station.

Each zone (Native Woodland and Cultured Woodland) was analyzed in i-Tree separately, as listed below. The data for each zone was input for one (1) acre; the benefits were then extrapolated for the entire zone by multiplying each value by the zone acreage.

Native Woodland

Carbon Sequestration: 646.1 lbs (i-Tree Eco v6) for 400 trees of 10 species representing 1 acre of Native Woodland zone

$$646.1 \text{ lbs} * 9.72 \text{ acres (acreage of Native Woodland zone)} = 6,280 \text{ lbs} = \mathbf{3.14 \text{ tons}}$$

Avoided Runoff: 450.4 cu. ft./year (i-Tree Eco v6) for 400 trees of 10 species representing 1 acre of Native Woodland zone

$$450.4 \text{ cu. ft./year} * 9.72 \text{ acres (acreage of Native Woodland zone)} = 4,378 \text{ cu. ft.} = \mathbf{32,750 \text{ gallons}}$$

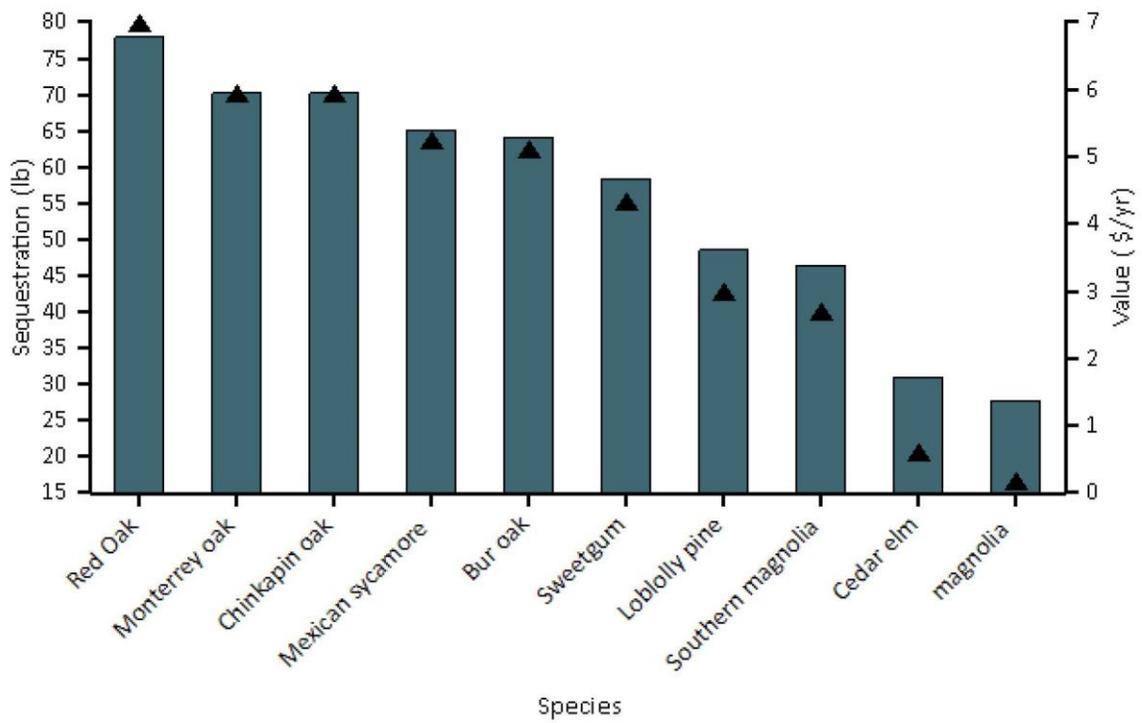


Figure 6: Estimated Gross Annual Carbon Sequestration for Species with the Greatest Sequestration (i-Tree Eco v6)

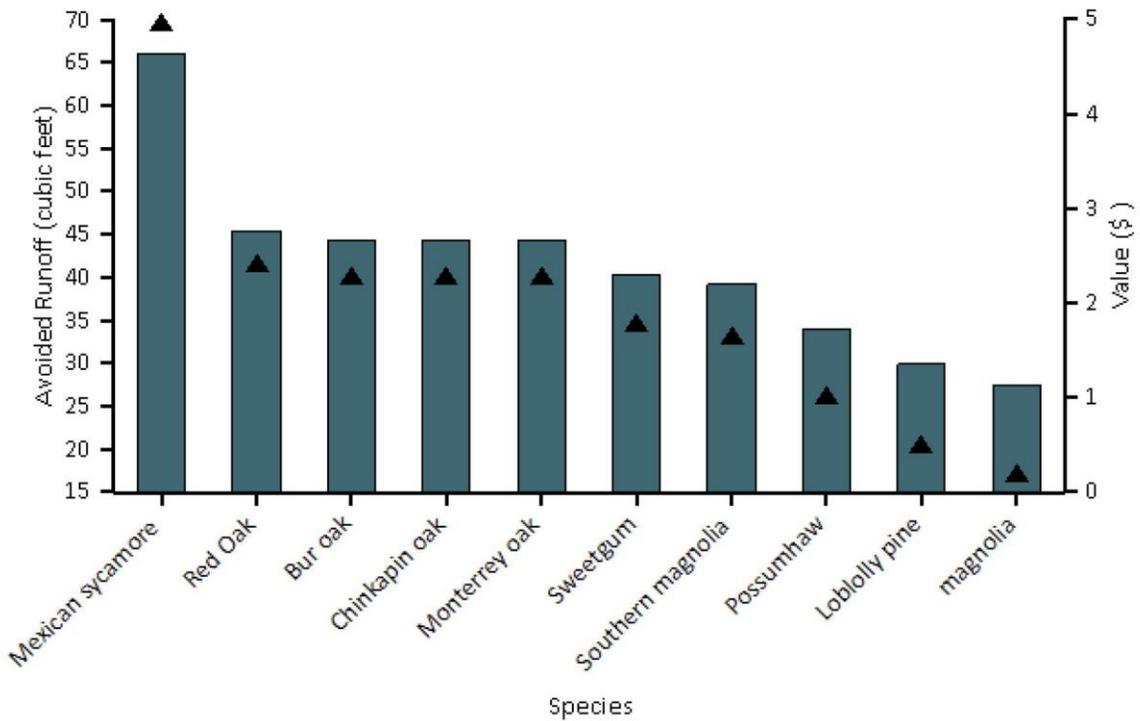


Figure 7: Avoided Runoff for Species with the Greatest Overall Impact on Runoff (i-Tree Eco v6)

Cultured Woodland

Carbon Sequestration: 824.5 lbs (i-Tree Eco v6) for 400 trees of 8 species representing 1 acre of Cultured Woodland zone

824.5 lbs*14.67 acres (acreage of Cultured Woodland zone) = 12,095 lbs = **6.05 tons**

Avoided Runoff: 468.2 cu. ft./year (i-Tree Eco v6) for 400 trees of 8 species representing 1 acre of Cultured Woodland zone

468.2 cu. ft./year*14.67 acres (acreage of Cultured Woodland zone) = 6,869 cu. ft. = **51,384 gallons**

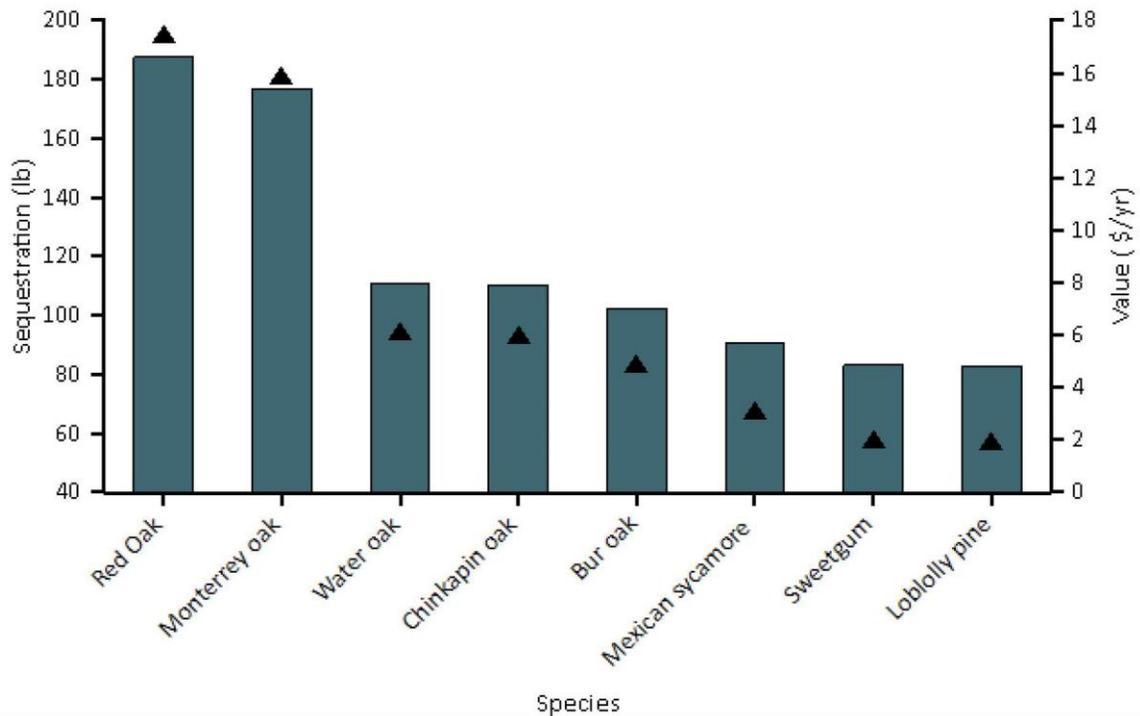


Figure 8: Estimated Gross Annual Carbon Sequestration for Species with the Greatest Sequestration (i-Tree Eco v6)

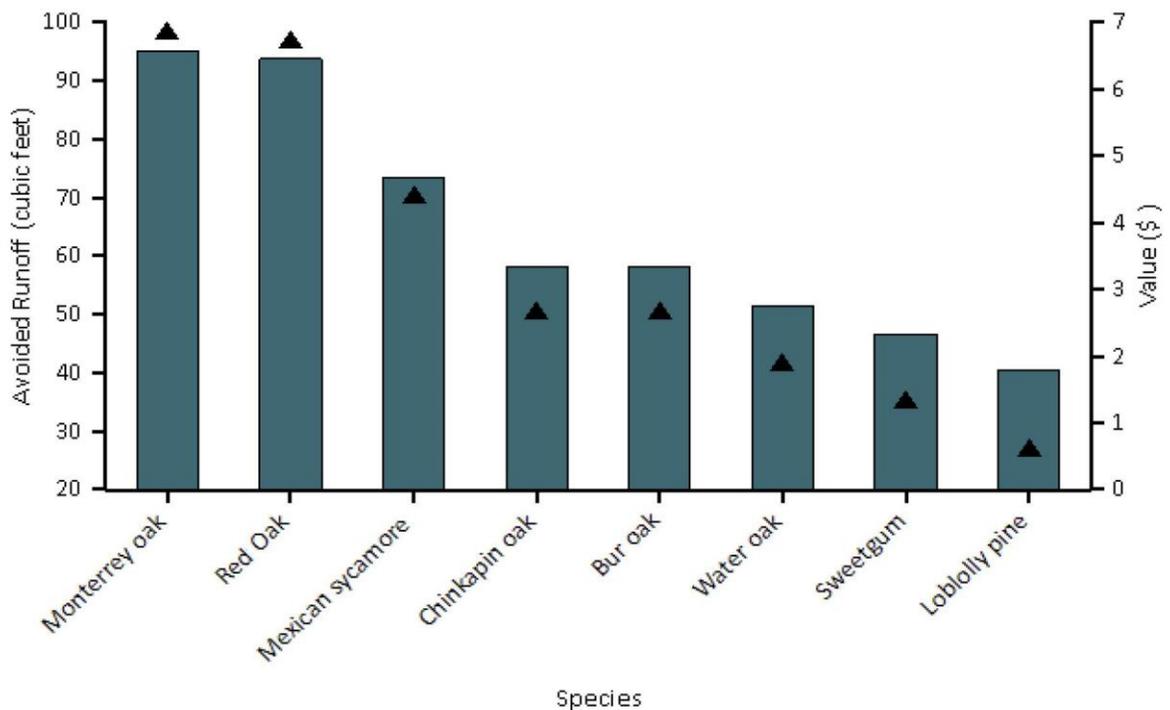


Figure 9: Avoided Runoff for Species with the Greatest Overall Impact on Runoff (i-Tree Eco v6)

3.14 tons + 6.05 tons = **9.19 tons**

32,750 gallons + 51,384 gallons = **84,134 gallons**

Sources:

i-Tree Eco v6. Accessed May 14, 2019. <https://www.itreetools.org/eco/index.php>

Tree species lists and breakdowns were provided by the landscape architect, SWA.

Limitations:

The tree species and breakdowns used for these calculations were based off of the original construction documents provided by the landscape architect. These calculations do not account for changes in the field during construction or ongoing maintenance, replacement, or repair. Additionally, two planting zones were used for this calculation as mentioned above (Native Woodland and Cultured Woodland) which comprise a majority of the trees on site with significant sequestration benefits. However, the remaining zones (Riparian Bayou Edge, Garden Areas, and Specimen Trees) were not used in this calculation.

Average species DBH rather than each individual tree DBH was used for the calculations. Therefore, the result is an approximation, not an exact value.

Additionally, i-Tree does not take into account groundcover and while shrubs can be taken into account, they were not included in this analysis. The benefits discussed above will increase over time.

Social Benefits

1. **Attracted an estimated 12,000 daily visitors over 11 fall days in 2016. From June 2018 to May 2019, average daily bike share use of stations adjacent to the park ranged from 619 in February to 1,064 in April.**

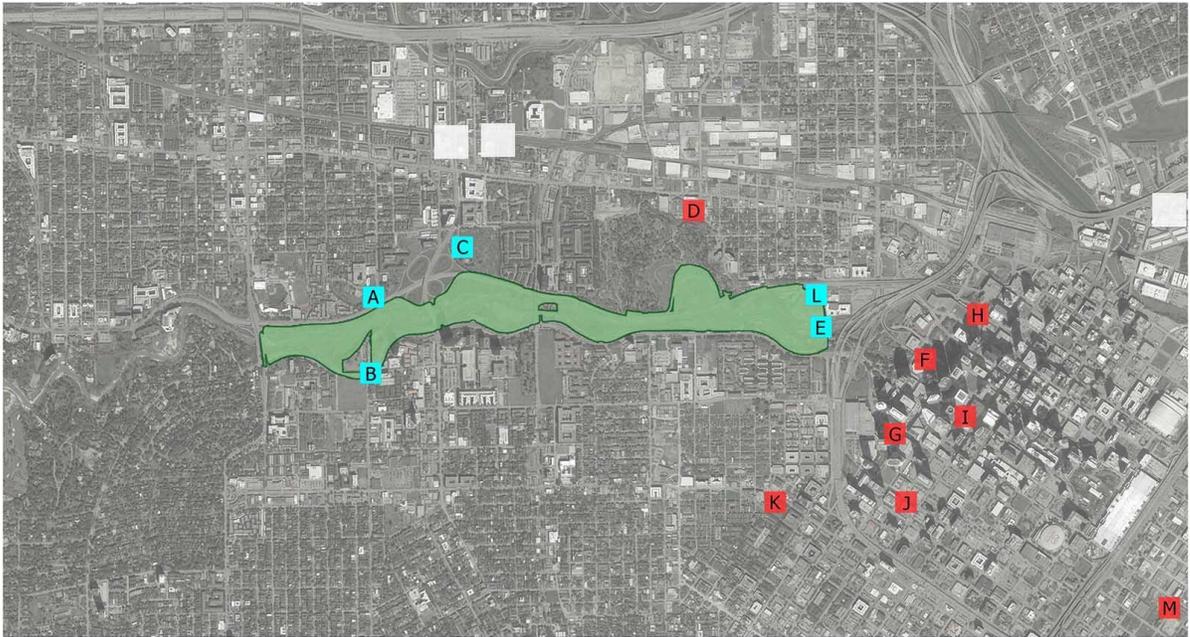
Methods:

User counts from bike share companies were obtained from June of 2018 to June of 2019 and were compared to pedestrian and cyclist user counts collected in September and October of 2016.

Calculations:

Bike share data was collected from three companies with stations present in/near the park: BCycle, Bike Barn, and EaDo. Collectively, these companies have thirteen station locations throughout and surrounding the park for users to access. The data collected was categorized by monthly bike rentals per station from June of 2018 to June of 2019. Each monthly total was then divided by 30 (average days per month) to determine the daily average for bike rentals. The daily averages per month were then used to determine an overall daily average. The 5 stations immediately adjacent to the park were used to determine the final daily average.

Pedestrians and cyclists were counted on trails within the park by temporary trail counters (TRAFx Infrared Trail Counters: Generation III) by the Houston-Galveston Area Council. This technology does not differentiate between pedestrians and cyclists therefore the total number of users is an undetermined mix. This data was collected from September 30, 2016 to October 10, 2016 and determined an estimated 11,945 daily users.



MAP KEY

- | | | |
|---|-----------------------------|---------------------------------|
| A) Jackson Hill & Memorial Drive (BCycle) | F) City Hall (BCycle) | K) West Gray & Baldwin (BCycle) |
| B) Lost Lake (BCycle) | G) Clay & Smith (BCycle) | L) Bayou Rentals (BikeBarn) |
| C) Spotts Park (BCycle) | H) Smith & Capitol (BCycle) | M) Downtown (EaDo) |
| D) Washington (BCycle) | I) Lamar & Milam (BCycle) | |
| E) Sabine Bridge (BCycle) | J) Tellepsen (BCycle) | |

Figure 10: Bike Share Station Locations

Company	Bike Station Name	19-May	19-Apr	19-Mar	19-Feb	19-Jan	18-Dec	18-Nov	18-Oct	18-Sep	18-Aug	18-Jul	18-Jun	Daily Average
BCycle	Jackson Hill	403	527	442	257	340	225	286	402	329	447	474	416	
	Lost Lake	469	412	358	184	307	228	223	386	240	297	371	352	
	Spotts Park	809	719	746	366	661	436	408	526	330	592	616	561	
	Washington	154	126	135	76	128	84	109	147	61	70	151	135	
	Sabine Bridge	2641	2960	2708	1589	2016	1705	1546	2119	1417	2333	2216	2291	
	City Hall	557	388	328	236	257	216	215	339	376	395	408	454	
	Clay & Smith	377	320	200	169	194	94	148	234	250	296	336	243	
	Smith & Capitol	314	293	211	113	238	148	197	239	163	249	305	292	
	Lamar & Milam	446	455	332	212	181	275	231	265	270	351	351	343	
	Tellepsen	350	384	280	210	198	179	240	354	254	262	254	361	
West Gray & Baldwin	488	483	400	248	314	254	211	365	276	298	381	403		
BikeBarn	Bayou Rentals	700	700	700	700	700	700	700	700	700	700	700	700	
EaDo	Downtown	41	41	41	41	41	42	42	42	42	42	42	42	
Monthly Total		7749	7808	6881	4401	5575	4586	4556	6118	4708	6332	6605	6593	
Daily Average Per Month		258	260	229	147	186	153	152	204	157	211	220	220	200
Annual Total (2018-2019)		71,912												

Figure 11: Bike Share Counts - All Stations (2018 - 2019)

Company	Bike Station Name	19-May	19-Apr	19-Mar	19-Feb	19-Jan	18-Dec	18-Nov	18-Oct	18-Sep	18-Aug	18-Jul	18-Jun	Daily Average
BCycle	Jackson Hill	403	527	442	257	340	225	286	402	329	447	474	416	
	Lost Lake	469	412	358	184	307	228	223	386	240	297	371	352	
	Spotts Park	809	719	746	366	661	436	408	526	330	592	616	561	
	Sabine Bridge	2641	2960	2708	1589	2016	1705	1546	2119	1417	2333	2216	2291	
BikeBarn	Bayou Rentals	700	700	700	700	700	700	700	700	700	700	700	700	
Monthly Total		5022	5318	4954	3096	4024	3294	3163	4133	3016	4369	4377	4320	
Daily Average Per Month		1004	1064	991	619	805	659	633	827	603	874	875	864	818

Figure 12: Bike Share Counts - Stations A, B, C, E, and L (2018 - 2019)

Counter	Location	Avg. Daily Usage	Total Users	Page Number
H1	Buffalo Bayou North Bank: St. Thomas High School (Pedestrian Path)	139	1,529	7
H2	Buffalo Bayou North Bank: St. Thomas High School	1,172*	7,032*	12
H3	Buffalo Bayou South Bank: Lost Lake	1,180	12,984	17
H4	Buffalo Bayou South Bank: Johnny Steele Dog Park (Pedestrian Path)	N/A**	N/A**	22
H5	Buffalo Bayou South Bank: Johnny Steele Dog Park (Main Shared-Use Path)	1,121	12,327	24
H6	Buffalo Bayou South Bank: Johnny Steele Dog Park (Roadside Shared-Use Path)	676	7,431	29
H7	Buffalo Bayou North Bank: Green Tree Nature Area	1,529	16,814	34
T1	Buffalo Bayou North Bank: Police Memorial	1,681	18,490	39
T2	Buffalo Bayou North Bank: Nature Play Area (Sabine Street Access)	966	10,626	44
T3	Buffalo Bayou North Bank: Nature Play Area (Main Shared-Use Path)	598	6,577	49
T4	Buffalo Bayou North Bank: Nature Play Area (Pedestrian Path)	380	4,183	54
T5	Buffalo Bayou South Bank: Eleanor Tinsley Park	1,539	16,924	59
T7	Memorial Drive Westbound: West of Shepherd Drive	133	1,462	64
T8	Memorial Drive Eastbound: West of Shepherd Drive	387	4,260	68
T9	Memorial Drive Eastbound at East Terrace Drive	171	1,882	72
T10	Kirby Drive Southbound: West of Shepherd Drive	237	2,608	76
T11	Kirby Drive Northbound: West of Shepherd Drive	64	705	80
T12	Shepherd Drive Southbound: South of Kirby Drive/Allen Parkway	104	1,149	84
T13	Shepherd Drive Northbound: South of Kirby Drive/Allen Parkway	88	963	88
T14	Pedestrian/Bicycle Bridge at Shepherd Drive	952	10,470	92
TOTAL		11,945	131,384	

* The data is from September 30 to October 10, 2016 Total user counts (131,384)/11 days = Average daily user counts

Figure 13: Pedestrian/Cyclist Counts (Houston-Galveston Area Council)

Sources:

BCycle. Station Maps. Accessed on June 11, 2019.

<https://www.houstonbicycle.com/houston-bstations>

Bike Count Data (Raw). BCycle Houston Bike Share, Development & Communications. Henry Morris.

Bike Count Data. BikeBarn, Owner. Neil Brewner.

Bike Count Data. EaDo, Owner. Nathan Marquez.

BikeBarn. Locations. Accessed on June 18, 2019.

<https://www.bikebarn.com/about/buffalo-bayou-rentals-pg1892.htm>

EaDo. Store Locator. Accessed on June 18, 2019.

<https://www.eadobikeco.com/storelocator/>

H-GAC, Pedestrian and Bicyclist Counters. Accessed June 6, 2019. <http://www.h-gac.com/pedestrian-bicyclist-planning/counters.aspx>

Limitations:

Bike share data was provided by the respective companies and was not independently verified by the research team.

Since Bike Barn provided only annual data and EaDo provided data in six month periods, the daily averages were extrapolated by the research team.

Additionally, BCycle is a bike share program that provides a service for transportation and recreation while EaDo aims to provide a service for primarily recreation and athletic purposes. Bike Barn's service is a combination of these two approaches.

The pedestrian/cyclist data provided by the Houston-Galveston Area Council was from September and October of 2016. This data would be more accurate with a counting analysis having occurred more recently, however organizations and councils with these resources were not conducting this type of analysis at the time of this study. Additionally, the research team did not collect this data and therefore did not independently verify.

- 2. Provides additional and improved park access for over 21,000 households within a half-mile. Of these 38,000 residents, 8.1% live in poverty, 36% are minorities, and 5.8% are people with disabilities.**

Methods:

Using a combination of American Community Survey (ACS) data and ESRI ArcGIS software, a ½ mile buffer zone around the park periphery was defined. The smallest scale of geographic units was determined for the census block groups in order to analyze the population data within the buffer zone. Components of the population data were then extracted including residents living within the buffer zone neighborhoods in addition to a breakdown of vulnerable residents who are living in poverty, Hispanic, non-Hispanic, disabled, elderly, without a personal car, and single parents.

Calculations:

A combination of ACS data and ESRI ArcGIS software was used to extract population data.

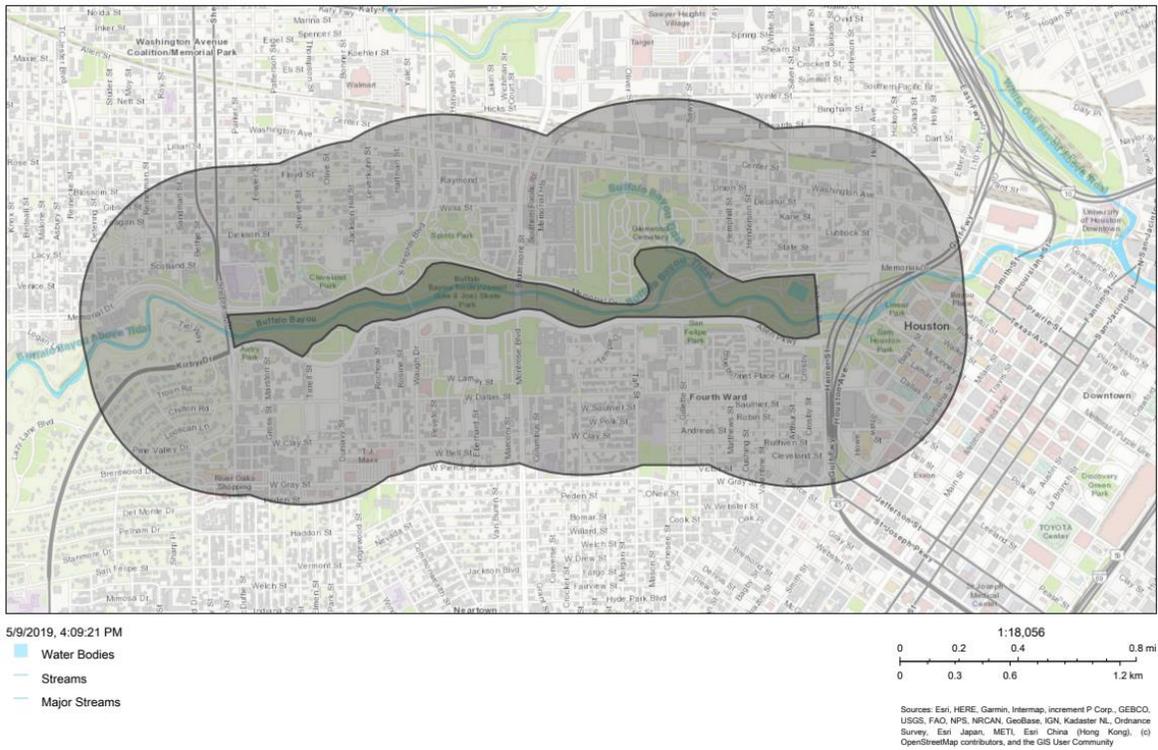


Figure 14: Buffalo Bayou Park ½ Mile Buffer Zone (ESRI ArcGIS)

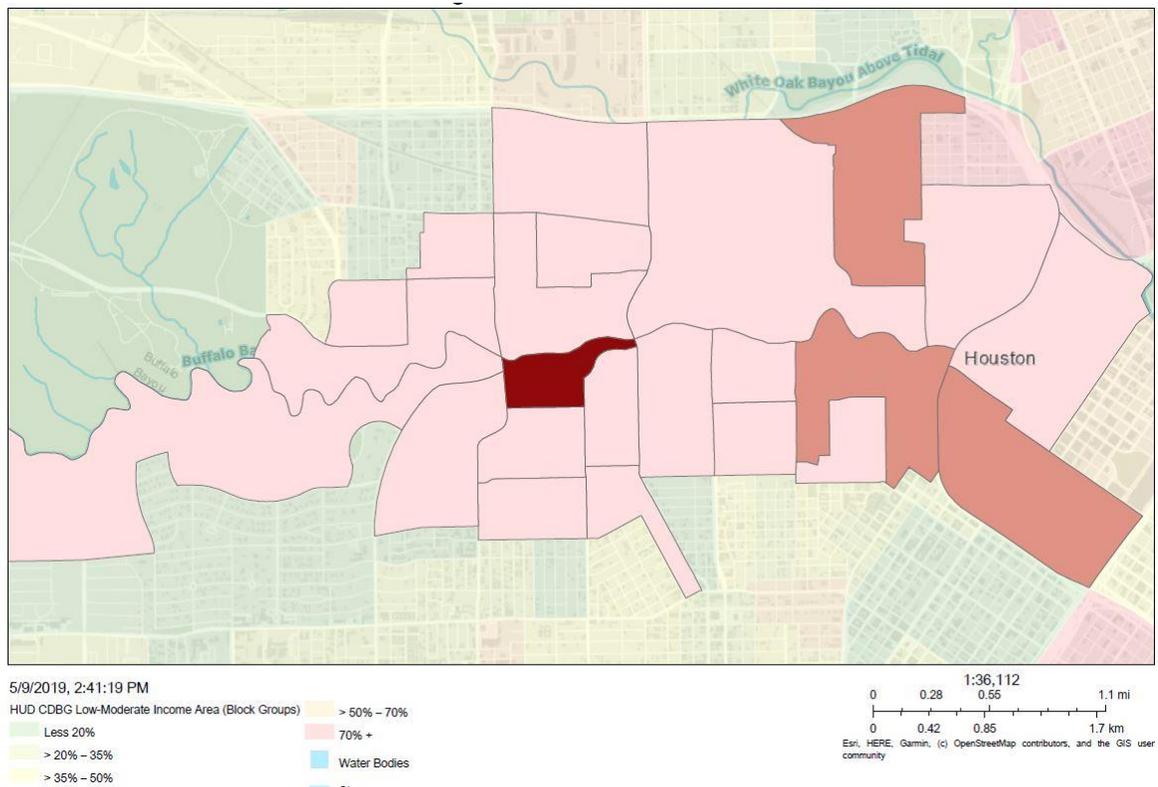


Figure 15: Buffalo Bayou Park Block Groups (ESRI ArcGIS)

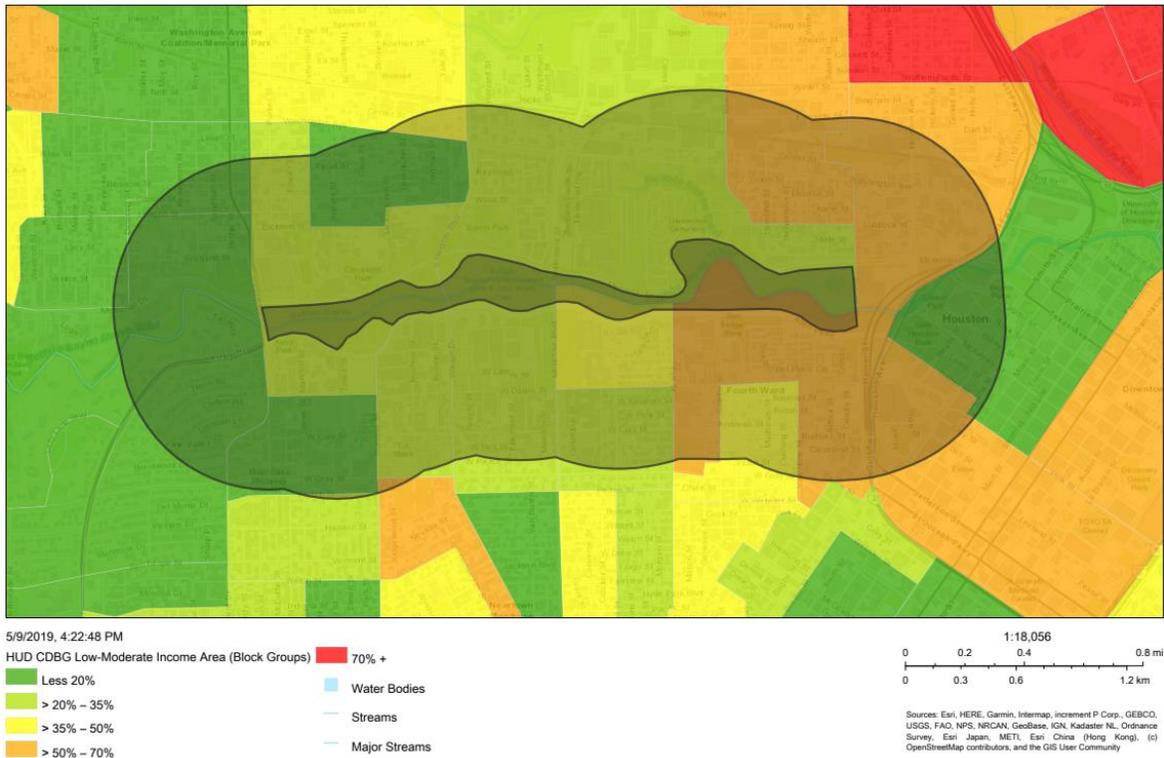


Figure 16: Buffalo Bayou Park Income Groups (ESRI ArcGIS)

$(3,150 \text{ residents living in poverty} / 38,861) * 100 = \mathbf{8.1\%}$
 $(6,863 \text{ Hispanic minorities} / 38,861) * 100 = \mathbf{17.7\%}$
 $(7,130 \text{ Non-Hispanic minorities} / 38,861) * 100 = \mathbf{18.3\%}$
 $17.7\% + 18.3\% = \mathbf{36\% \text{ total minorities}}$
 $(2,269 \text{ residents with disabilities} / 38,861) * 100 = \mathbf{5.8\%}$
 $(1,274 \text{ elderly residents} / 38,861) * 100 = \mathbf{3.3\%}$
 $(837 \text{ residents with no personal car} / 38,861) * 100 = \mathbf{2.2\%}$
 $(417 \text{ single parent households} / 21,076) * 100 = \mathbf{2.0\%}$

Note: only full block groups that fit entirely within the half mile buffer were included in this analysis and the metadata provided the numbers within these block groups used in the calculations above.

Sources:

American Community Survey. 2017.

City of Houston GIS (COHGIS) parks data. Retrieved May 11, 2019 from <https://cohgis-mycity.opendata.arcgis.com/>

ESRI ArcGIS Tools for mapping and figures.

Houston-Galveston Area Council (HGAC). Regional Data Lab. Regional Flood Information. Accessed on July 13, 2019: <http://www.h-gac.com/interactive-web-applications/default.aspx>

The Trust for Public Land. ParkScore Index. 2019. Accessed on July 13, 2019 from <https://parkscore.tpl.org/evaluator/evaluator.html?city=Houston&idx=38>

Limitations:

The software collates and cross references many types of spatial datasets by location and is continuously updated. However, the software can sometimes inherit errors or inaccuracies every time a new dataset is imported which can skew results.

- 3. Contributes to a self-reported decrease in physical ailments such as stress, asthma, and general poor health since beginning to come to the park according to 78% of 76 survey respondents who were repeat visitors.**

Methods:

A user survey was developed to assess the amenities and services preferred by people visiting the site and was offered in English and Spanish. The survey was administered on June 14, 2019 and June 15, 2019 from 9 am to 5 pm. The research team rotated between locations of frequent circulation and occupancy and asked visitors if they would be interested in taking a survey about the site and its amenities. Completed survey results were entered into a digital Qualtrics survey platform and were analyzed. The full survey can be found in Appendix A.

Calculations:

Question: Have you noticed a decrease in physical ailments such as, stress, asthma, and general poor health since you started coming to the park?

59 respondents answered "Yes"

$$59/(89-13) = 59/76 = .776*100 = 77.6\%$$

30 respondents answered "No"

13 respondents were first time visitors

89 total respondents

Self-reported first time visitors of the park (N=13) were eliminated from this analysis so that only repeat visitors were included to analyze this decrease.

Sources:

Survey Questions (refer to Appendix A)

Survey administration was conducted by the research team with additional administration provided by the Buffalo Bayou Partnership through social media outlets.

Limitations:

The sample size was limited due to the number of hours the research team could spend on the site. The research team was aware of bias that can occur with convenience sampling. The team inquired with as many visitors as possible in order to obtain respondents for the survey. In order to supplement the total number of respondents obtained on site, the survey was also administered online and was sent to the general public and park employees through social media platforms and through email. This was accomplished with the help of the client, Buffalo Bayou Partnership.

4. Contributes to improved quality of life and sense of well-being according to 90% of 89 survey respondents.

Methods:

A user survey was developed to assess the amenities and services preferred by people visiting the site and was offered in English and Spanish. The survey was administered on June 14, 2019 and June 15, 2019 from 9 am to 5 pm. The research team rotated between locations of frequent circulation and occupancy and asked visitors if they would be interested in taking a survey about the site and its amenities. Completed survey results were entered into a digital Qualtrics survey platform and were analyzed. The full survey can be found in Appendix A.

Calculations:

Question: Could you rate the following statements regarding your experience with Buffalo Bayou Park?

80 respondents highly rated "Visiting the park improves my quality of life and sense of well-being."

$$80/89 = .899 * 100 = \mathbf{89.9\%}$$

72 respondents highly rated "Access to the park is easy."

$$72/89 = .809 * 100 = \mathbf{80.9\%}$$

77 respondents highly rated "The park provides diverse recreational activities."

$$77/89 = .865 * 100 = \mathbf{86.5\%}$$

72 respondents highly rated "I feel safe and secure when I am in the park."

$$72/89 = .809 * 100 = \mathbf{80.9\%}$$

71 respondents highly rated "I can describe the park as a pleasant place to be overall."

$$71/89 = .798 * 100 = \mathbf{79.8\%}$$

41 respondents highly rated "I have an understanding of the cultural and historical importance of the park."

$$41/89 = .461 * 100 = \mathbf{46.1\%}$$

89 total respondents

Sources:

Survey Questions (refer to Appendix A)

Survey administration was conducted by the research team with additional administration provided by the Buffalo Bayou Partnership through social media outlets.

Limitations:

The sample size was limited due to the number of hours the research team could spend on the site. The research team was aware of bias that can occur with convenience sampling. The team inquired with as many visitors as possible in order to obtain respondents for the survey. In order to supplement the total number of respondents obtained on site, the survey was also administered online and was sent to the general public and park employees through social media platforms and through email. This was accomplished with the help of the client, Buffalo Bayou Partnership.

- 5. Provides educational and cultural opportunities as demonstrated by the 30,000 people who attended Historic Cistern Tours in the park in 2018, a 58% increase from 2016 attendance.**

Methods:

Event data was provided by the Buffalo Bayou Partnership in order to calculate the increase in attendees for the Historic Cistern tour from 2016 to 2018.

Calculations:

Historic Cistern Tour

2018: 30,000 attendees

2017: 30,000 attendees

2016: 19,000 attendees

$30,000 - 19,000 = 11,000$

$(11,000/19,000)*100 = 57.89\%$

Sources:

Event data was provided by the Buffalo Bayou Partnership.

Limitations:

This data was not collected by the research team.

6. Helps to educate visitors about design solutions with 93% of 89 survey respondents able to identify at least one strategy to protect the bayou from flooding.

Methods:

A user survey was developed to assess the amenities and services preferred by people visiting the site and was offered in English and Spanish. The survey was administered on June 14, 2019 and June 15, 2019 from 9 am to 5 pm. The research team rotated between locations of frequent circulation and occupancy and asked visitors if they would be interested in taking a survey about the site and its amenities. Completed survey results were entered into a digital Qualtrics survey platform and were analyzed. The full survey can be found in Appendix A.

Calculations:

Question: Which of the following would you consider the most effective potential solution to protecting the bayou from flooding? (You may choose up to four)

66 respondents answered "Local & Native Plants"

$$66/89 = .742 * 100 = \mathbf{74.2\%}$$

34 respondents answered "Proper Maintenance"

$$34/89 = .382 * 100 = \mathbf{38.2\%}$$

29 respondents answered "Planted Bayou Banks"

$$29/89 = .326 * 100 = \mathbf{32.6\%}$$

28 respondents answered "Curve the Bayou"

$$28/89 = .315 * 100 = \mathbf{31.5\%}$$

89 total respondents

93% of respondents chose at least one correct answer (listed above). Only 7% of respondents chose incorrect answers including "Straighten the Bayou," "Concrete Bayou Banks," and "Non-Native Plants" or chose "Other/No Response".

Respondents were also asked about the educational activities they might have attended at the park regarding flood protection for the bayou and the park's resilient design. 20 participants responded that they have attended guided walking tours informing them about the bayou. Additionally, 27 respondents noted that they had also attended Cistern Tours and Boat Tours.

Sources:

Survey Questions (refer to Appendix A)

Survey administration was conducted by the research team with additional administration provided by the Buffalo Bayou Partnership through social media outlets.

Limitations:

The sample size was limited due to the number of hours the research team could spend on the site. The research team was aware of bias that can occur with convenience sampling. The team inquired with as many visitors as possible in order to obtain respondents for the survey. In order to supplement the total number of respondents obtained on site, the survey was also administered online and was sent to the general public and park employees through social media platforms and through email. This was accomplished with the help of the client, Buffalo Bayou Partnership.

7. Visually connects park users with downtown Houston as demonstrated by 45% of over 2,300 social media posts about the space referring to both the skyline and the park.

Methods:

A number of overlooks, viewing areas, plazas, pavilions, and seating areas exist throughout the park in choreographed manner to allow visitors to engage with the bayou (whereas previously, it was far less visually and physically accessible due to overgrown vegetation) and to offer views across the park and toward the Houston skyline. Social media was used to quantify the value of these views by cross-referencing the following hashtags/tagged locations across various platforms.

Hashtags:

#buffalobayoupark (500)
#waughbridgebatcolony (100)
#rosemontbridge (100)
#jamaillskatepark (100)
#eleanortinsleypark (100)
#policeofficersmemorial (100)

1000 of the most recent posts for 6 hashtags/tagged locations (representing 5 of the major overlooks and viewing areas within the park in addition to the primary Buffalo Bayou Park hashtag) from 3 social media platforms were then visually reviewed for photos that included the Houston skyline. This method was used for both Instagram and Facebook. Due to the total quantity of available posts for Twitter being lower than the other platforms, the number of analyzed posts was adjusted for each hashtag.

Calculations:

Park hashtags/tagged locations visually referencing the Houston skyline.

Instagram (Posts identified on June 11, 2019)

#buffalobayoupark $209/500 = .418 * 100 = 41.8\% = 42\%$
#waughbridgebatcolony $9/100 = .09 * 100 = 9\%$

#rosemontbridge 66/100 = .66*100 = 66%
#jamailskatepark 25/100 = .25*100 = 25%
#eleanortinsleypark 61/100 = .61*100 = 61%
#houstonpoliceofficersmemorial 61/100 = .61*100 = 61%

Average:
(42% + 9% + 66% + 25% + 61% + 61%)/6 = **44%**

Facebook (Posts identified on June 13, 2019)

@ Buffalo Bayou Park 200/500 = .40*100 = 40%
@ Waugh Bridge Bat Colony 24/100 = .24*100 = 24%
@ Rosemont Bridge 50/100 = .50*100 = 50%
@ Jamail Skate Park 23/100 = .23*100 = 23%
@ Eleanor Tinsley Park 61/100 = .61*100 = 61%
Houston Police Officers Memorial N/A (removed from calculation)

Average:
(40% + 24% + 50% + 23% + 61%)/5 = **40%**

Twitter (Posts identified on June 19, 2019)

#buffalobayoupark 168/300 = .560*100 = 56.% = 56%
#waughbridgebatcolony 1/5 = .20*100 = 20%
#rosemontbridge 10/13 = .769*100 = 77%
#jamailskatepark 7/24 = .291*100 = 29%
#eleanortinsleypark 17/38 = .447*100 = 45%
#houstonpoliceofficersmemorial 7/9 = .777*100 = 78%

Average:
(56% + 20% + 77% + 29% + 45% + 78%)/6 = **51%**

Total Average:
(44% + 40% + 51%)/3 = **45%**

Sources:

<https://www.instagram.com/>
<https://www.facebook.com/>
<https://twitter.com/>

Limitations:

Certain social media platforms allow users to share posts across platforms. This could have resulted in duplicate counts for posts.

Social media posts that referenced multiple hashtags in a single post may have resulted in duplicate counts.

There is potential for human error in excluding photos not actually referencing the hashtags that were used for this calculation.

Economic Benefits

1. Reduced turf maintenance costs by an estimated 54%, saving \$52,600 annually in labor costs for mowing.

Methods:

Previously a drainage corridor, the site had twice as much acreage of mown turf as the current park. Using data from the Maintenance Plan for Buffalo Bayou Park, the annual labor cost for mowing turf within the park was determined by multiplying the number of hours spent mowing on average by a market hourly rate for compensation provided. In addition, the annual labor costs for meadow and riparian zone cutbacks were determined as they comprise areas that were once mown turf prior to the park construction. Additional zones were listed below as well in order to note the full scope of planting and hardscape areas that replaced mown turf area. The annual labor cost method was then applied to the site pre-construction for comparison.

Calculations:

Buffalo Bayou Park

Turf: 1,676 hours annually for 38 acres (Maintenance Plan)

$\$25/\text{hr} \times 1,676 \text{ hrs} = \underline{\$41,900/\text{year}}$

Meadows: 124 hours annually for 15.2 acres (Maintenance Plan)

$\$25/\text{hr} \times 124 \text{ hrs} = \underline{\$3,100/\text{year}}$

Riparian: 38 hours annually for 4.8 acres (Maintenance Plan)

$\$25/\text{hr} \times 38 \text{ hours} = \underline{\$950/\text{year}}$

Native Woodland: 9.72 acres - no mowing

Cultured Woodland: 14.67 acres - no mowing

Hardscape: 7 acres - no mowing

Total: \$45,950/year

Pre-Construction

Turf: 3,943 hours annually for 89.4 acres (44.1 hours annually/acre extrapolated from Maintenance Plan)

$\$25/\text{hr} * 3,943 \text{ hrs} = \mathbf{\$98,575/\text{year}}$

$98,575 - 45,950 = 52,625$

$(\$52,625/\$98,575) * 100 = \mathbf{53.39\%}$

Sources:

ETM Associates, LLC. Maintenance Plan for Buffalo Bayou Park: Post-Schematic Design. March 2012. Task and Budget Estimates

Additional mown turf data was provided by the landscape architect, SWA.

Limitations:

The annual hour data was not collected by the research team.

The Maintenance Plan references all components of maintenance for each of these planting categories. However, only the mowing maintenance costs for labor were calculated for this analysis, and many other benefits could be evaluated from the decrease in lawn area.

- 2. Contributed to a 13% average increase in the median property tax revenue for owner-occupied homes in the surrounding census tracts from 2013 to 2017, compared to a 7% increase for Harris County as a whole.**

Methods:

The U.S. Census Bureau American Fact Finder was used to access census and American Community Survey data before and after the construction of the park from 2013 and 2017. The American Community Survey produces population, demographic, and housing unit estimates along with data on real estate taxes. For comparison, the five census tracts adjacent to the park were analyzed and compared to Harris County median data.

Calculations:

Property Taxes Census Tracts 4101, 4102, 4103, 5102, 5107:

Median dollars (2017): 3,633, 6,977, 5,844, 7,357, 8,099

Median dollars (2013): 4,277, 5,722, 5,354, 6,064, 6,433

Amount of Change: -644, +1,255, +490, +1,293, + 1,666

Percent Change: -15.06%, +21.93%, +9.15%, +21.32%, +25.90%

Average: $(-15.06\% + 21.93\% + 9.15\% + 21.32\% + 25.90\%) / 5 = \mathbf{12.65\%}$

Property Taxes in Harris County:

Median dollars (2017): 3,221

Median dollars (2013): 3,009

Amount of Change: +212

Percent Change: **7.05%**

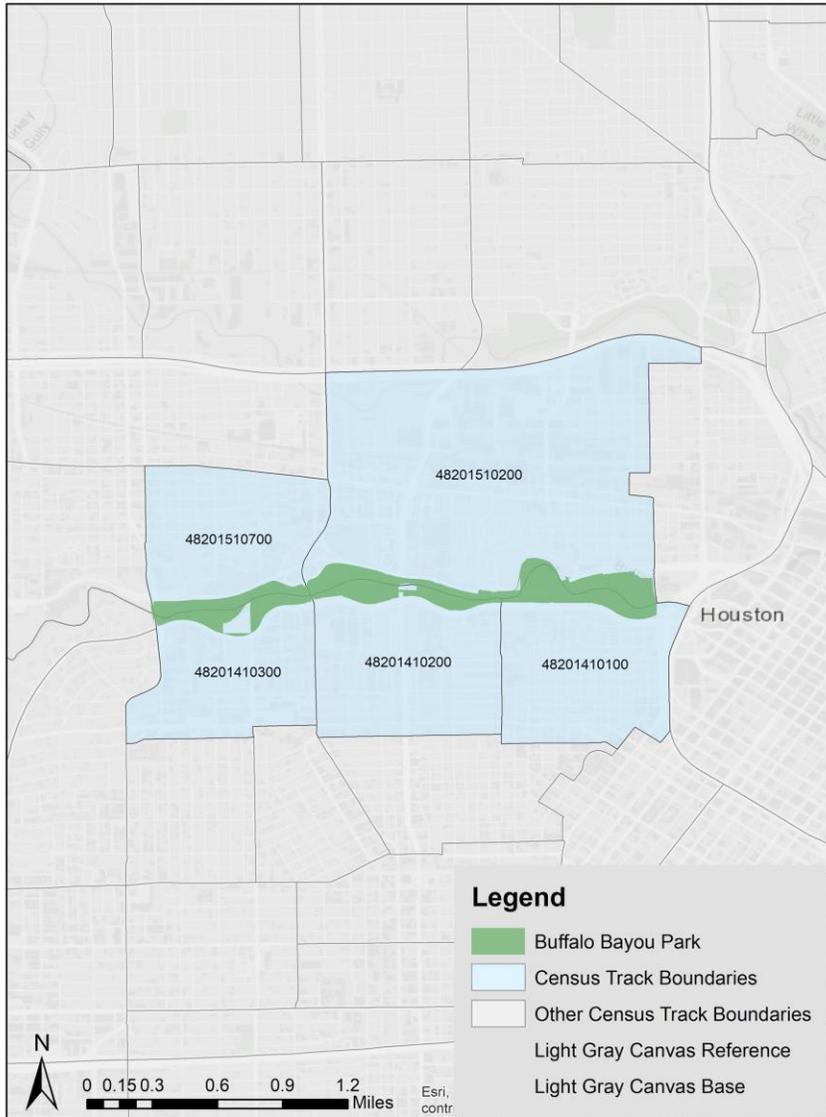


Figure 19: Census Tracts (ESRI ArcGIS)

	Harris County, Texas		Census Tract 4101, Harris County, Texas		Census Tract 4102, Harris County, Texas		Census Tract 4103, Harris County, Texas		Census Tract 5102, Harris County, Texas		Census Tract 5107, Harris County, Texas	
	Estimate	Margin of Error	Estimate	Margin of Error	Estimate	Margin of Error	Estimate	Margin of Error	Estimate	Margin of Error	Estimate	Margin of Error
2017	Median real estate taxes paid --											
	Total:											
	3,221	+/-23	3,633	+/-1,806	6,977	+/-793	5,844	+/-922	7,357	+/-1,005	8,099	+/-424
	Median real estate taxes paid for units with a mortgage											
	3,619	+/-27	3,800	+/-1,618	7,983	+/-3,425	5,211	+/-1,203	7,337	+/-1,270	8,127	+/-456
	Median real estate taxes paid for units without a mortgage											
	2,360	+/-37	-	**	6,071	+/-702	6,928	+/-1,405	7,528	+/-4,172	7,560	+/-1,961
2013	Median real estate taxes paid --											
	Total:											
	3,009	+/-24	4,277	+/-406	5,722	+/-686	5,354	+/-853	6,064	+/-728	6,433	+/-527
	Median real estate taxes paid for units with a mortgage											
	3,381	+/-26	4,234	+/-546	6,135	+/-765	4,825	+/-1,016	6,517	+/-658	6,612	+/-545
	Median real estate taxes paid for units without a mortgage											
	2,113	+/-37	4,500	+/-1,034	4,222	+/-2,820	7,065	+/-1,696	1,656	+/-3,241	2,559	+/-5,507
	Amount of change		-644		1,255		490		1,293		1,666	
	Percentage change		-15.06%		21.93%		9.15%		21.32%		25.90% 12.64%	

Figure 20: Calculations for Median Property Tax Revenue (United States Census Bureau)

Sources:

American Community Survey. United States Census Bureau - American Fact Finder. Accessed May 19th, 2018. <https://factfinder.census.gov>

ESRI ArcGIS Mapping Tools

United States Census Bureau - American Fact Finder. Accessed May 19, 2018. <https://factfinder.census.gov>

Limitations:

2017 was the most recent data available for median property tax revenue in the area. Additionally, many factors outside of the park can also contribute to these increases. The data used in this calculation is only collected for owner-occupied units.

3. Catalyzed more than \$2 billion worth of investment within a 3-block radius of the park from 2013 to 2019.

Methods:

Investment dollar amounts for completed and ongoing development projects adjacent to the park and known to the research team and the landscape architect were researched and collected from development companies. These projects all capitalize on the presence of the park through direct association with the park (developments containing Buffalo Bayou in their names, partnerships, etc.) and through promoting park adjacency, activities, and opportunities for residents and occupants through marketing material and websites.

Calculations:

The following investment data was collected from development companies:

Buffalo Heights District (mixed use district)
Developer: Midway
\$233 million

The Allen (mixed use)
Developer: DC Partners
\$454 million

Broadstone Tinsley Park (residential)
Developer: Alliance Residential Company
\$39.9 million (land purchase only)

Regent Square
Developer: GID Development
\$1.5 billion

Total: 2.3 billion

Additional developments not releasing investment information at the time of this analysis:

Hanover Buffalo Bayou (mixed use)
Developer: The Hanover Company

Houston Endowment Offices

Ismaili Cultural Center - Aga Khan Foundation

Riva at the Park (residential)
Developer: Sims Luxury Builders

Park Place (office)
Developer: Pinto Partners

Jefferson Heights (residential)
Developer: JPI

LJB Apartments (residential)
Developer: LJB

Sources:

Chron, H-E-B “urban prototype”. Accessed on June 5, 2019, <https://www.chron.com/business/real-estate/article/H-E-B-urban-prototype-breaks-ground-near-11130544.php#photo-12866645>

“Construction and Development”. GID. Accessed May 21, 2019. <https://www.gid.com/our-capabilities/development/>

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Houston Architecture, Broadstone Tinsley Park. Accessed on June 6, 2019, <https://www.houstonarchitecture.com/haif/topic/30184-broadstone-tinsley-park-by-alliance-residential/>

Houston Business Journal. \$500 million mixed-use development. Accessed on June 6, 2019. <https://www.bizjournals.com/houston/news/2016/06/22/mixed-use-development-slated-for-site-near-buffalo.html>

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Midway, 2018 Impact Report. Accessed on June 6, 2019. https://issuu.com/midway2/docs/midway_annual_report_web_pages?e=28821381/68277785

Midway, Publications. Accessed on June 5, 2019. <https://midwaycompanies.com/who-we-are/publications#category=Publications>

SWA-Surrounding & Future Developments Document, 2019.

Yelp. Broadstone Tinsley Park. Accessed on June 5, 2019. <https://www.yelp.com/biz/broadstone-tinsley-park-houston> (Photo credits: User name: Sara M.)

Limitations:

This analysis includes as many development projects as were known to the research team, but there are a number of other development projects that are not included. Numerous developers with projects that have been announced and awarded were not releasing investment data at the time of this analysis and therefore could not be included.

Additionally, developers of the included projects provided investment amounts, therefore they were not independently verified by the research team.

COST COMPARISON

A series of riparian bank stabilization techniques were considered during the design phase of Buffalo Bayou Park in order to control for bank erosion from fluctuating water levels throughout the course of each flood season. Where creating a 3:1 slope (or even a more conservative 4:1 slope) was not possible due to constrained right-of-way, the preferred method was to install gabion walls along the banks of the bayou in combination with a 2:1 slope of planting above to limit the amount of erosion during flood events. However, at \$925.80 per linear foot (lf), installing gabion walls on both 2-mile-long banks was extremely cost-prohibitive. Instead, the design team stabilized the banks with vegetation at a 2:1 slope where wetland species would occupy the portion of the bank that would occasionally submerge, with a native grass mix above. Only a few locations were constructed with more aggressive stabilization techniques due to their high vulnerability for slope failure. Vegetated slope costs were \$72.50 per lf, most of which was already included in the planting budget.

However, due to the known vulnerable nature of vegetated slopes without gabion walls, repairs were necessary after Hurricane Harvey. The cost of repair for 4,315 lf of slope failures at \$748.50 per lf was \$3,229,778. If this same linear footage of banks had been initially constructed with gabion walls, that cost would have been \$3,994,827. While the repair costs for these vegetated slope failures totaled less than the cost to construct gabion walls in these locations, repetitive failures from future flooding events will cause this gap to shrink.

Methods:

Each stabilization method was priced per linear foot by the landscape architect and HCFCD in order to determine the best method for the project budget.

Calculations:

Each stabilization method was determined in the chart below. Additionally, the repair costs for the selected stabilization method from Hurricane Harvey were determined as well.

Buffalo Bayou Slope Stabilization Costs

	Qty	Unit	Unit Cost	Extension
Non-Stabilized Slope				
1 Do Nothing	0	sf	\$0.00	\$0.00
Cost Per Linear Foot				\$0.00
Lay Back Slope to 4:1				
1 Excavation	33.33	cy	\$10.00	\$333.30
2 Sod	124	sf	\$0.50	\$62.00
Cost Per Linear Foot				\$395.30
Vegetate Slope				
1 Riparian vegetation (lowland)	20	sf	\$2.50	\$50.00
2 Meadow (upland)	45	sf	\$0.50	\$22.50
				\$0.00
Cost Per Linear Foot				\$72.50
Buried Riprap (Stabilization and/or Repair)				
1 Riprap	5.6	cy	\$100.00	\$560.00
2 Soil	4.5	cy	\$35.00	\$157.50
3 Sod	62	sf	\$0.50	\$31.00
Cost Per Linear Foot				\$748.50
Coir Lifts				
1 Riprap	1.5	cy	\$100.00	\$150.00
2 Granular Fill	1.8	cy	\$166.00	\$298.80
3 Toewood	1	lf	\$150.00	\$150.00
4 Coir Fabric	20	sy	\$1.00	\$20.00
5 Imported Fill for Coir Lifts	4	cy	\$40.00	\$160.00
6 Coir Fiber Geogrid	1	lf	\$30.00	\$30.00
7 Live Stakes	18	ea	\$2.00	\$36.00
8 Meadow (upland)	40	sf	\$0.50	\$20.00
Cost Per Linear Foot				\$864.80
Gabions				
1 Gabion	2.7	cy	\$324.00	\$874.80
2 Riparian vegetation (lowland)	11	sf	\$2.50	\$27.50
3 Meadow (upland)	47	sf	\$0.50	\$23.50
Cost Per Linear Foot				\$925.80
Sheet Pile Wall				
1 Sheet Pile Wall	25	sff	\$40.00	\$1,000.00
2 Concrete Cap	0.148	cy	\$1,500.00	\$222.00
3 Meadow (upland)	47	sf	\$0.50	\$23.50
Cost Per Linear Foot				\$1,245.50

Notes:

- Construction cost only; does not include soft costs, design fees, contractor
- Does not include Right-of-Way acquisition

Figure 22: Stabilization Technique Cost Comparison, SWA

Site:

2.3 miles long (12,144 lf)
2 banks (north and south)

12,144 lf*2 = 24,288 lf

Vegetated Slopes:

\$72.50/lf

\$72.50/lf*24,288 lf = **\$1,760,880.00**

Gabion Walls:

\$925.80/lf

\$925.80/lf*24,288 lf = **\$22,485,830.40**

Cost of Vegetated Slope Repair:

\$748.50/lf

Length of slopes in need of repair: 4,315 lf (repair location data provided by the Harris County Flood Control District)

\$748.50/lf*4,315 lf = **\$3,229,778**

Cost of Same Linear Footage Having Been Constructed of Gabion Walls Initially:

\$925.80/lf

\$925.80/lf*4,315 lf = **\$3,994,827**

Repair Location	Station	Buried Riprap: Cost per LF		Gabion: Cost per LF		
		LF	Repair Cost/LF	Extension	Gabion Cost/LF	Extension
Bank			\$748.50		\$925.80	
South	18+50 to 19+20	70	\$748.50	\$52,395	\$925.80	\$64,806
North	22+00 to 24+00	200	\$748.50	\$149,700	\$925.80	\$185,160
North	46+00 to 61+75	1,575	\$748.50	\$1,178,888	\$925.80	\$1,458,135
South	78+00 to 86+50	850	\$748.50	\$636,225	\$925.80	\$786,930
North	78+00 to 83+20	520	\$748.50	\$389,220	\$925.80	\$481,416
South	98+00 to 106+00	800	\$748.50	\$598,800	\$925.80	\$740,640
South	109+00 to 112+00	300	\$748.50	\$224,550	\$925.80	\$277,740
		4,315		\$3,229,778		\$3,994,827

Figure 23: Slope Repairs - Vegetated Slopes (repaired with Buried Riprap) v. Initial Gabion Wall Construction for the Same Linear Footage

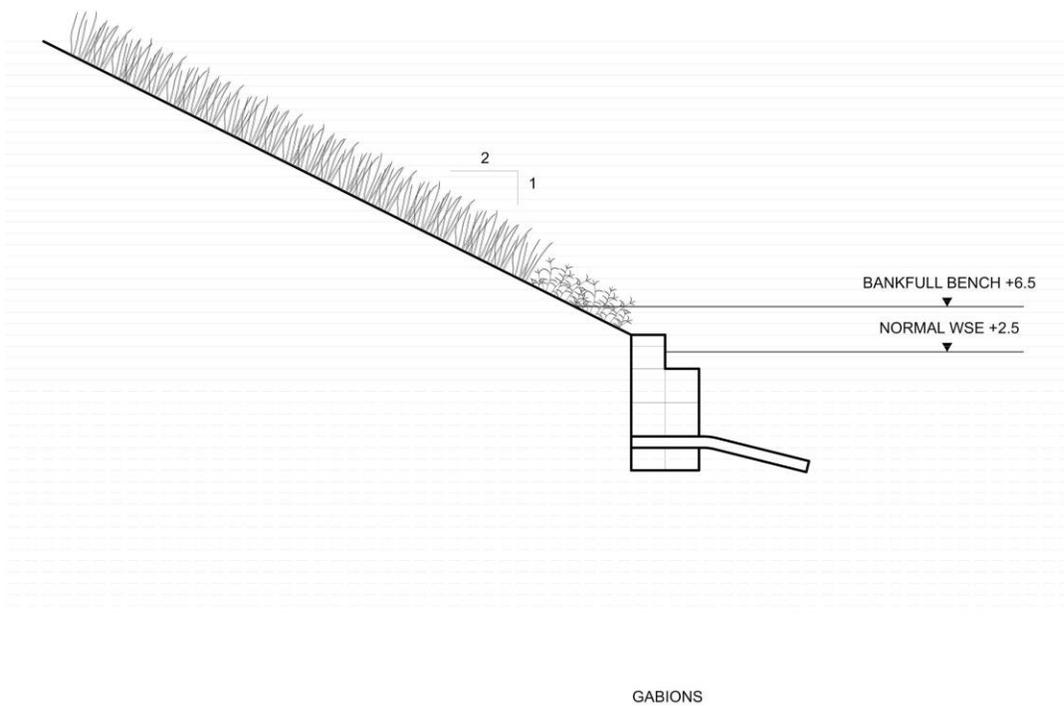
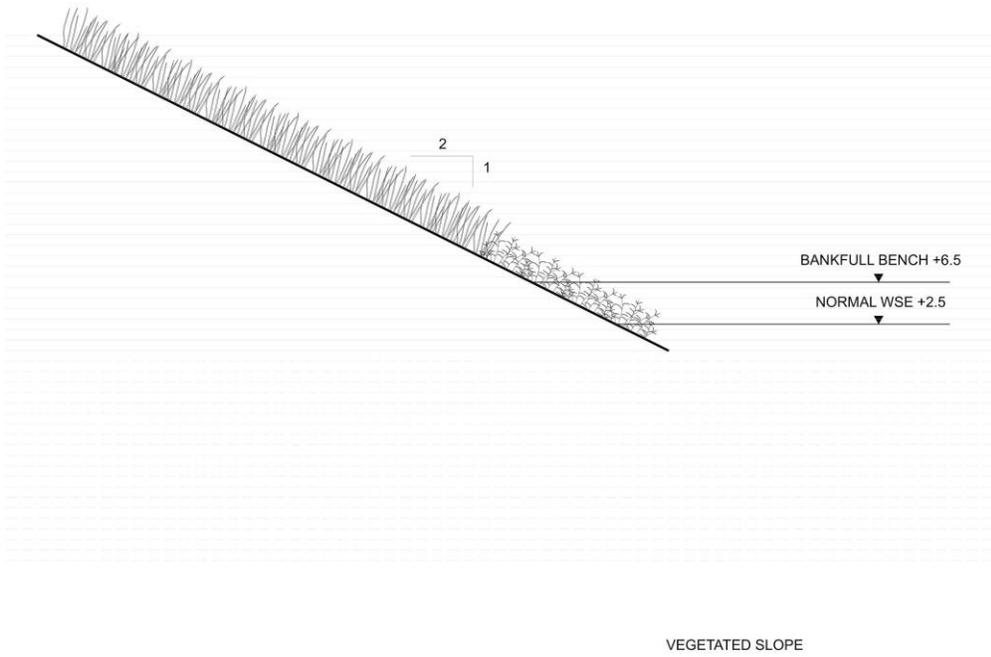


Figure 24: Stabilization Techniques - Vegetated Slope v. Gabion Walls

Sources:

Stabilization data was provided by the landscape architect, SWA, and the Harris County Flood Control District (HCFCD).

Limitations:

The costs determined for each stabilization technique are for construction costs only as they do not include soft costs, design fees, or contractor overhead.

High-level cost data was provided by the Harris County Flood Control District, however the research team extrapolated this data in order to determine some of the itemized criteria for this analysis.

Additionally, where certain banks do not meet the slope criteria for these techniques and exist in close proximity to property lines and Right-of-Way boundaries, their slopes and/or Right-of-Way boundaries needed to be adjusted or acquired. The costs determined here do not take into account Right-of-Way acquisition for those conditions.

INCONCLUSIVE BENEFIT

Contributed to a 68% average increase in assessed property value for 47 randomly selected parcels within a half-mile of the park from 2013 to 2019 and a 13% increase for parcels within a one-block radius from 2013 to 2019. For 62 randomly selected properties across the zip code area, the average increase was just 26%.

Methods:

Analysis was performed on 47 randomly selected units/parcels within a half-mile radius, in addition to 18 randomly selected units/parcels within a one-block radius, in order to understand the impact the park has made on neighboring property values. Unit and parcel data for property values within a specified period of time was obtained from the Harris County Appraisal District (HCAD) interactive map tool. Before finalizing the selection of units/parcels, data that was not accurately extracted or still pending was removed. The percentage increase in property value for each unit/parcel was calculated, upper and lower outliers were removed, and then the average for these units/parcels was used as a final estimate for the increase in property values from 2013 (before the park was constructed) to 2019 (current).

Overall, results did not indicate an increase in property value for properties within a half-mile and one block of the park strongly enough to attribute increases to the park,

although it could be assumed that this is likely the case. This benefit would require further study to verify the economic benefit.

Calculations:

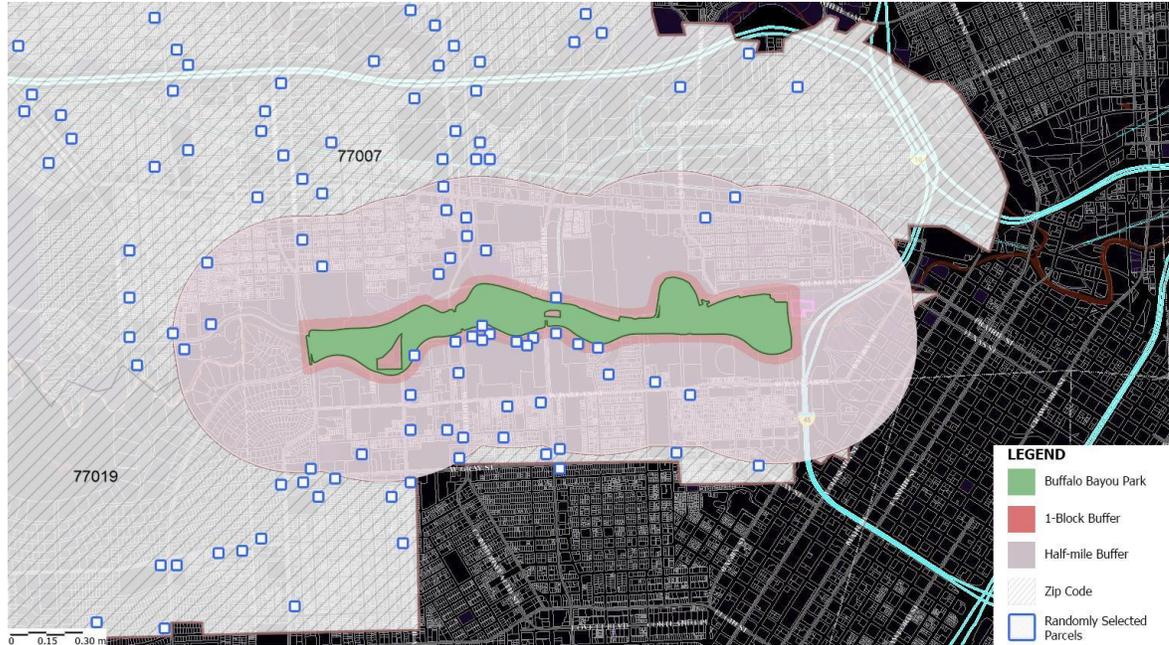


Figure 17: Buffalo Bayou Park Selected Units/Parcels Map (ESRI ArcGIS)

Two geographic scales were used to analyze property values (half-mile radius and one-block radius). The property values for the selected units/parcels were extracted from the Harris County Appraisal District between 2013 and 2019. The change in property values for each unit/parcel was converted to a percentage and listed in the table below. These percentages were then averaged to obtain the average increase in property value.

Of the 47 randomly selected parcels within a half-mile buffer, 34 parcels gained value with an average increase in value of 88% (calculated only for those that gained value except for 1 parcel as it was an outlier). Of the 18 randomly selected parcels within a one-block radius, 10 parcels gained value with an average increase in value of 106% (calculated only for those that gained value except for 1 parcel as it was an outlier). This was compared to the 62 randomly selected parcels within the same zip code where 37 parcels gained value with an average increase in value of 48% (calculated only for those that gained value except for 1 parcel as it was an outlier).

HALF MILE BUFFER	1-BLOCK BUFFER
-6.83%	102.18%
244.99%	0.00%
404.94%	-3.65%
-45.48%	15.03%
-15.07%	-24.45%
359.10%	-21.27%
167.00%	11.44%
183.54%	121.40%
29.19%	1553.21%
7.89%	62.74%
5.89%	46.41%
117.84%	176.80%
54.56%	-1.41%
20.77%	-20.55%
0.71%	-31.13%
46.12%	366.07%
7.95%	53.78%
-31.49%	-44.67%
17.81%	
-60.46%	
22.18%	
105.83%	
151.01%	
-38.70%	
-12.90%	
-5.42%	
-9.85%	
-78.24%	
-32.72%	
88.38%	
-9.13%	
639.02%	
228.86%	
18.59%	
-13.56%	
31.15%	
11.23%	
1.17%	
15.36%	
39.57%	
162.06%	
131.48%	
4.67%	
62.27%	
78.76%	
6.69%	
87.78%	
67.97%	131.22%

Figure 18: Buffalo Bayou Park Selected Units/Parcels Data (Harris County Appraisal District)

Sources:

Harris County Appraisal District., Property Search. Accessed on May 24, 2019

<http://hcad.org/property-search/business-personal-mineral/>

ESRI ArcGIS Tools for mapping and figures.

Limitations:

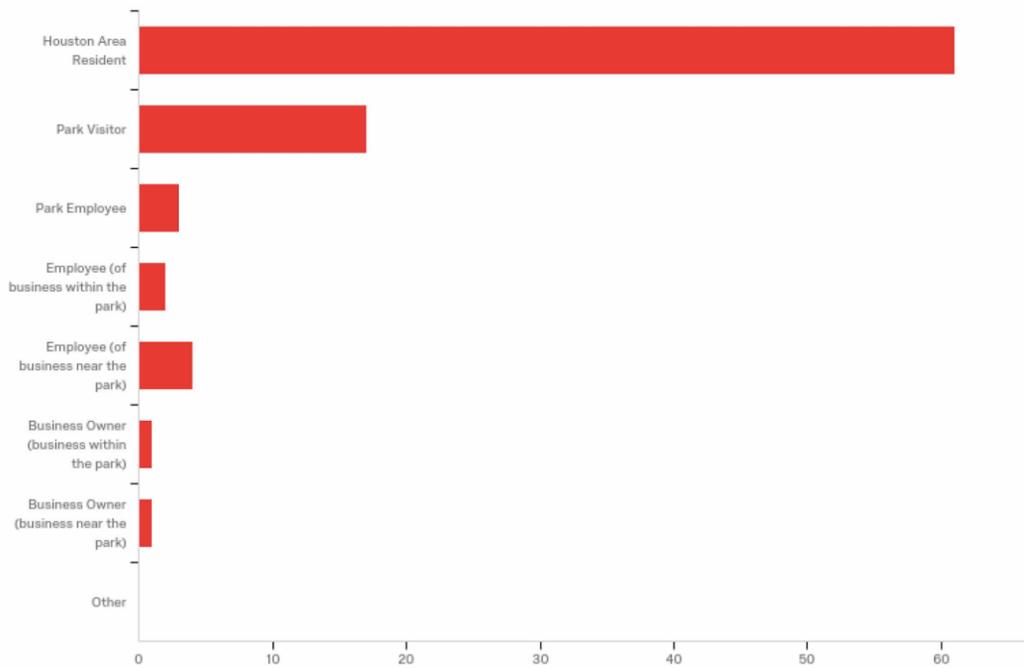
County level appraisal data was used for these calculations, therefore the accuracy of the data is dependent on the property value sources which the research team did not independently verify.

As a note, the unit/parcel locations were obtained from Google Maps and Google Earth and were enlarged in the maps for illustrative purposes.

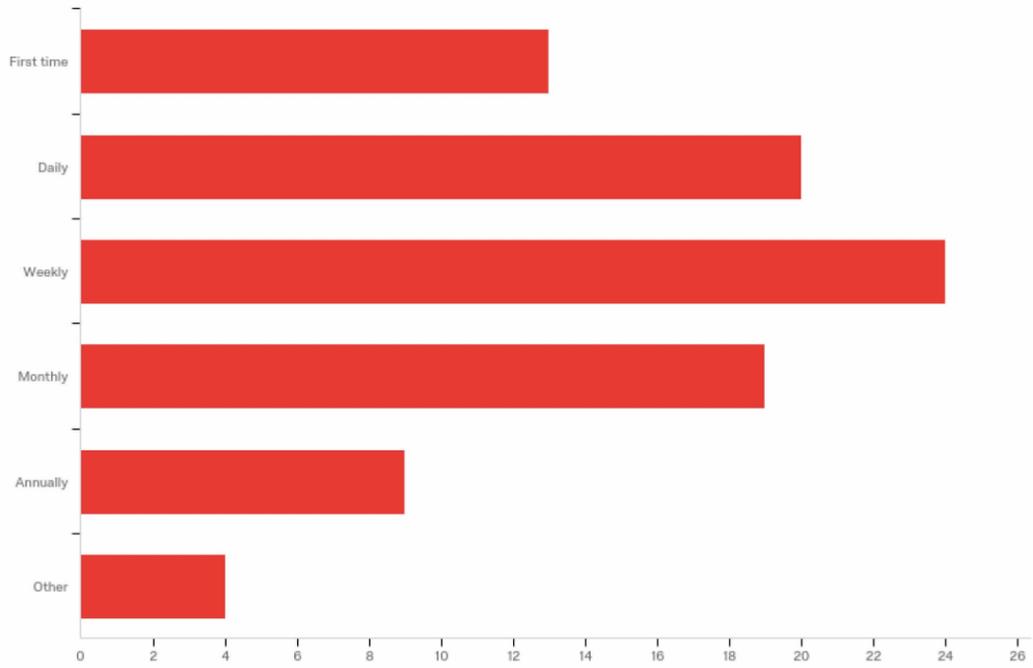
Appendix A

Survey Results

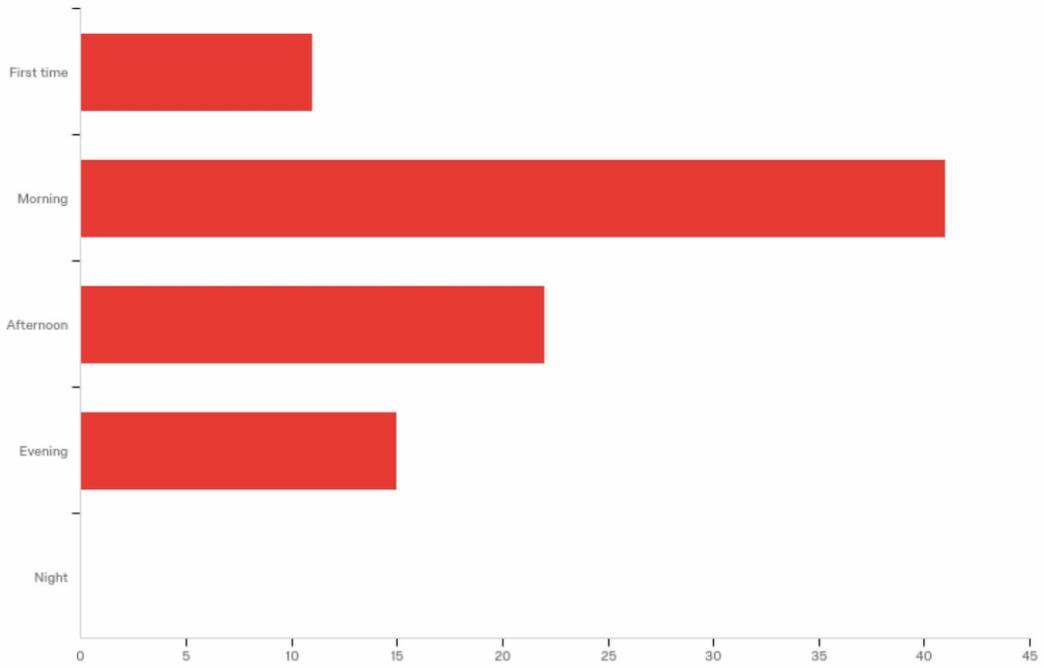
Q1 - Are you a:



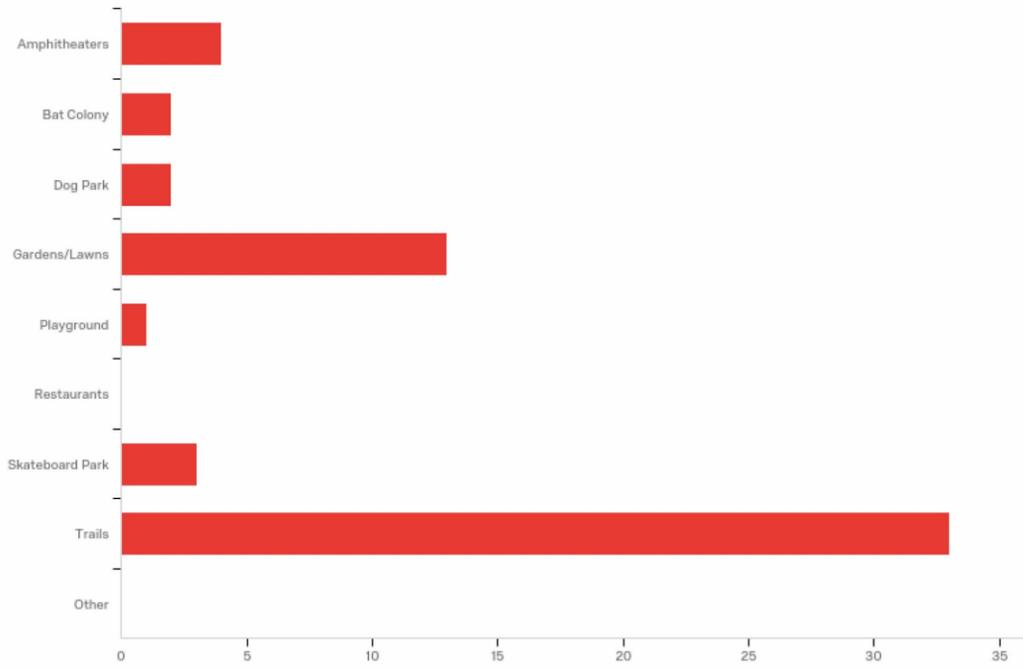
Q2 - Approximately how often do you typically visit the park?



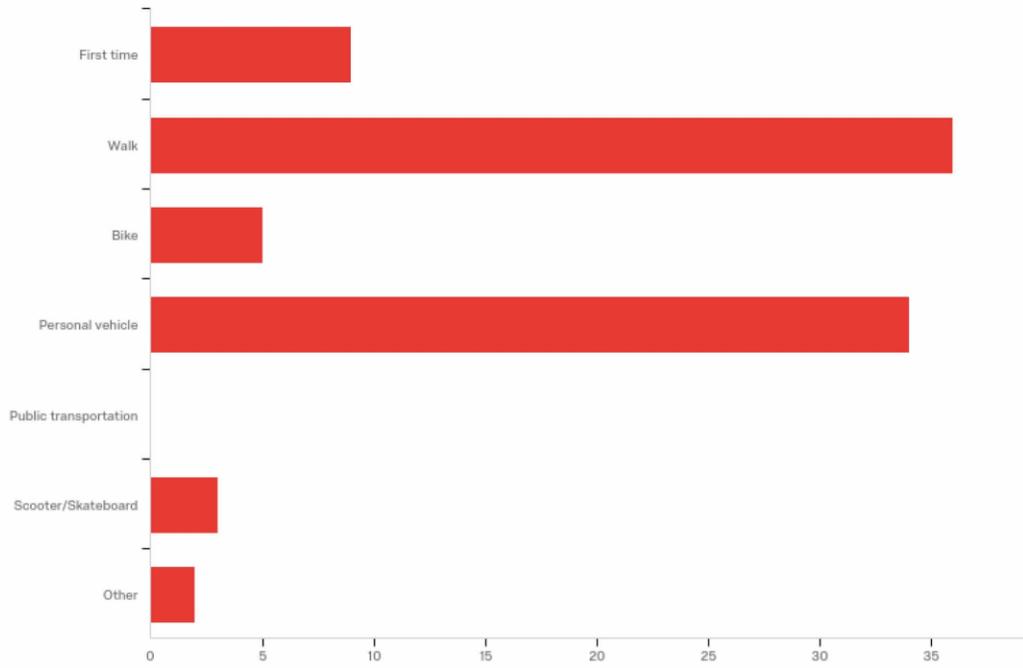
Q3 - What time of day do you typically visit the park?



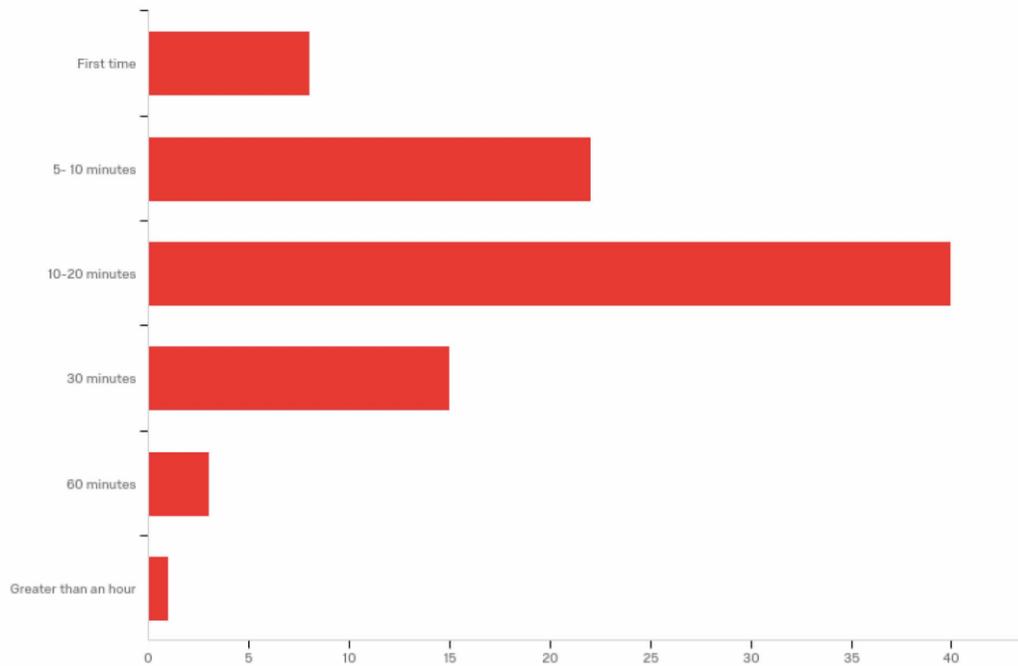
Q4 - What park elements do you most often use/visit at the park?



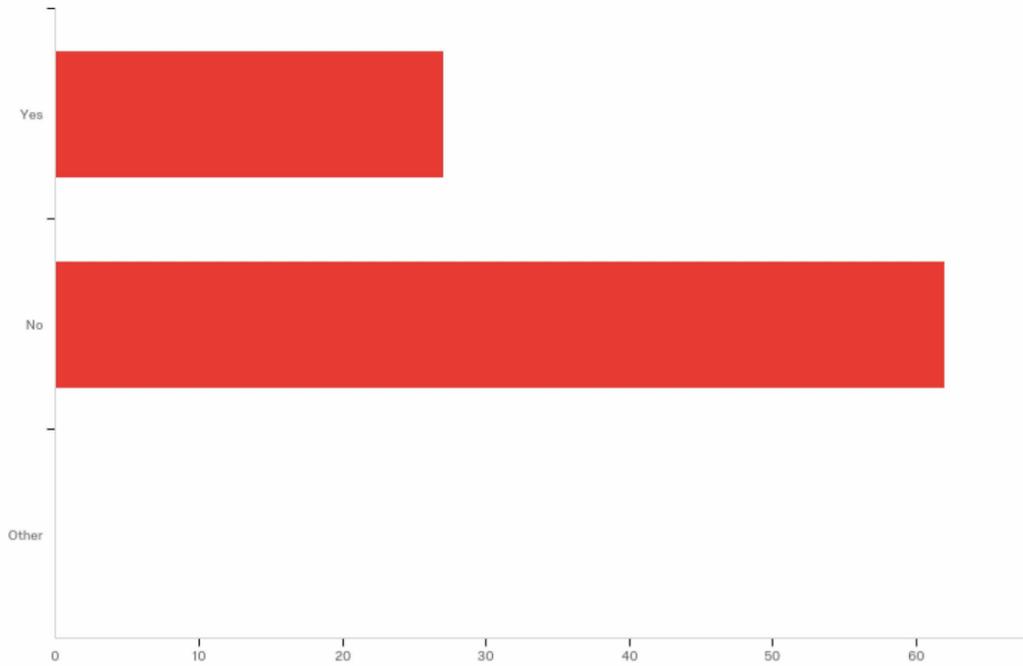
Q5 - How do you typically get to the park?



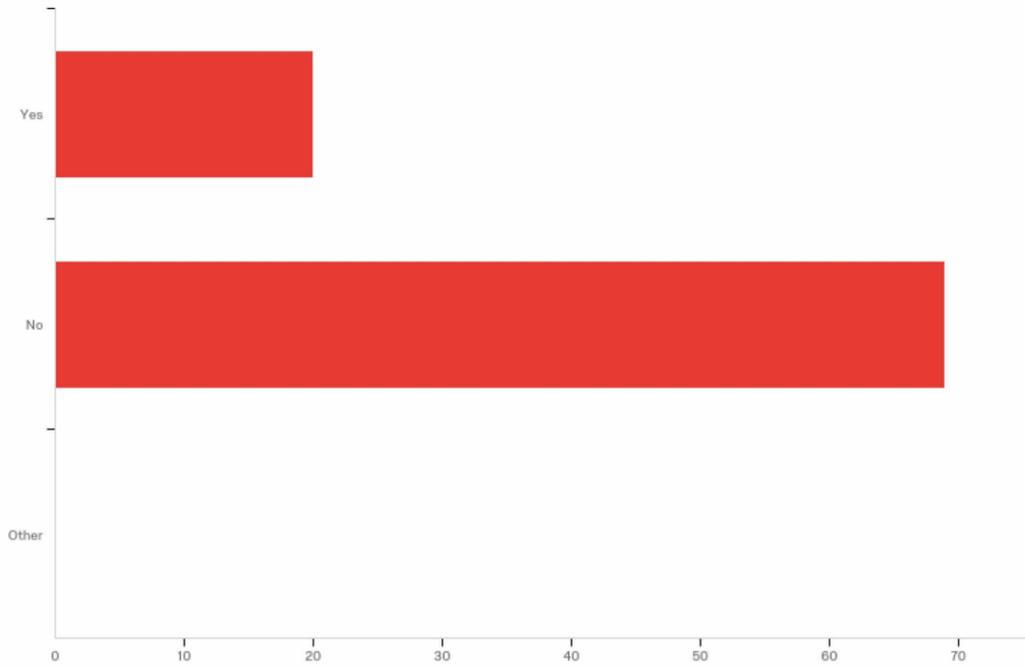
Q6 - How long did it/does it typically take you to the park? (Using that same mode)



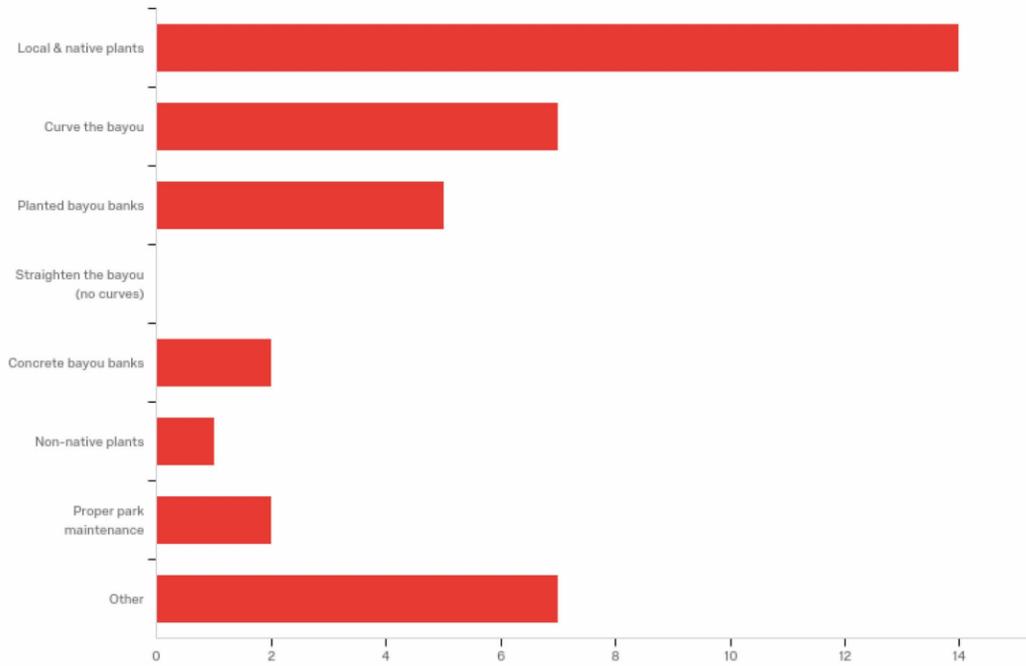
Q7 - Have you attended any events at the park? (Love Street Light Circus with Bayou Buddies, Buffalo Bayou Park Cistern Tour, Boat Tour, Walking Tour, Sunrise Yoga, etc.)



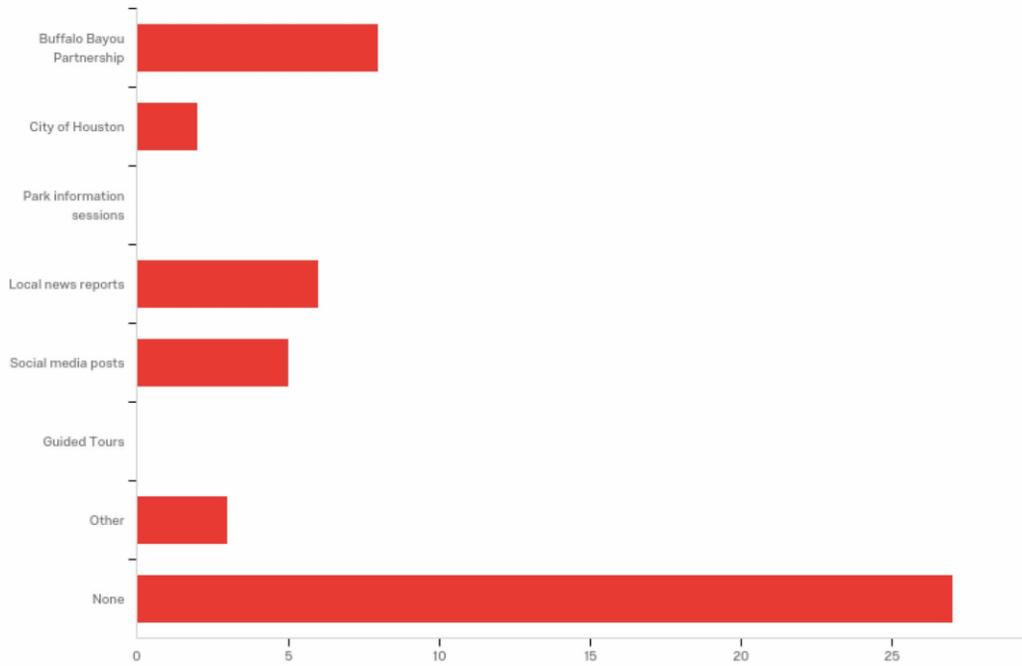
Q8 - Have you attended any educational activities in the Buffalo Bayou Park? (Information sessions, guided walking tours, boat tours, etc.)



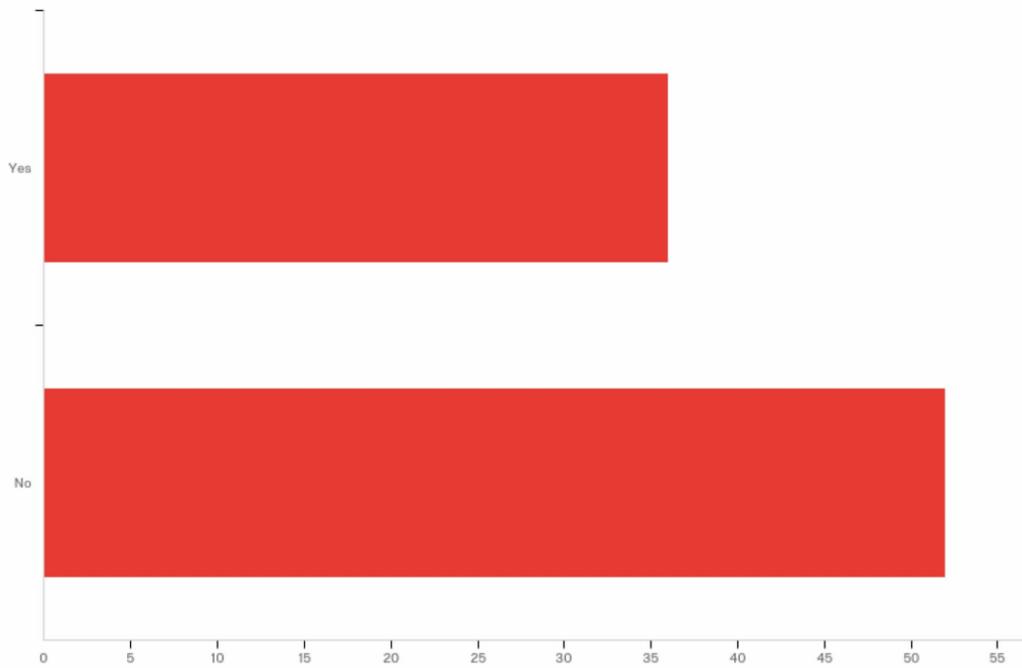
Q9 - Which of the following would you consider the most effective potential solution to protecting the bayou from flooding? (You may choose up to four)



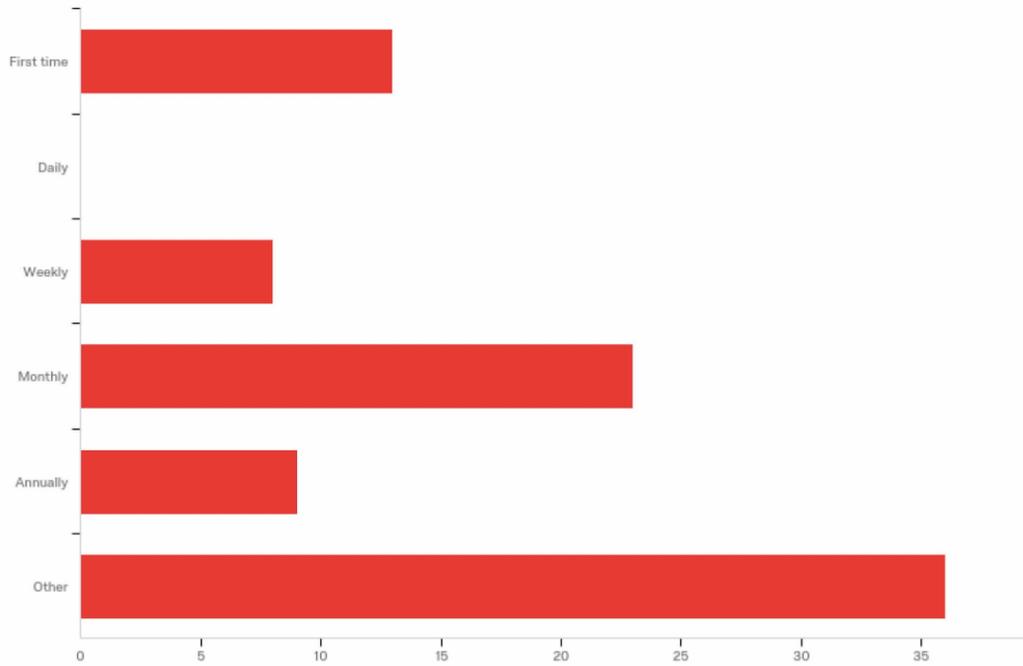
Q10 - How have you learned about flood protection with regard to Buffalo Bayou Park?



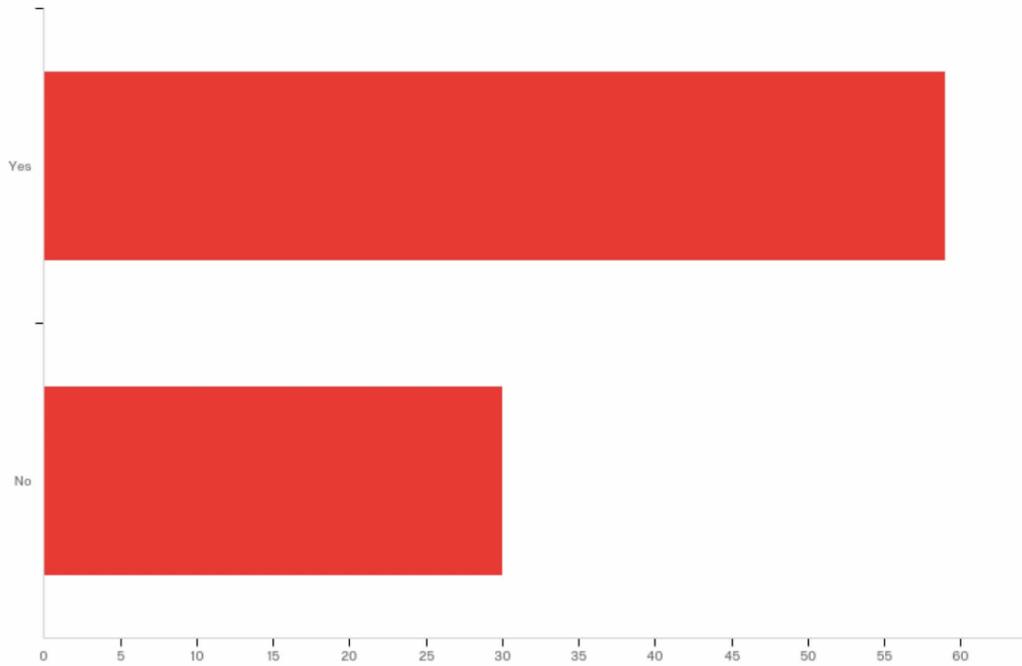
Q11 - Have you visited any nearby businesses/restaurants as part of your visit to the park?



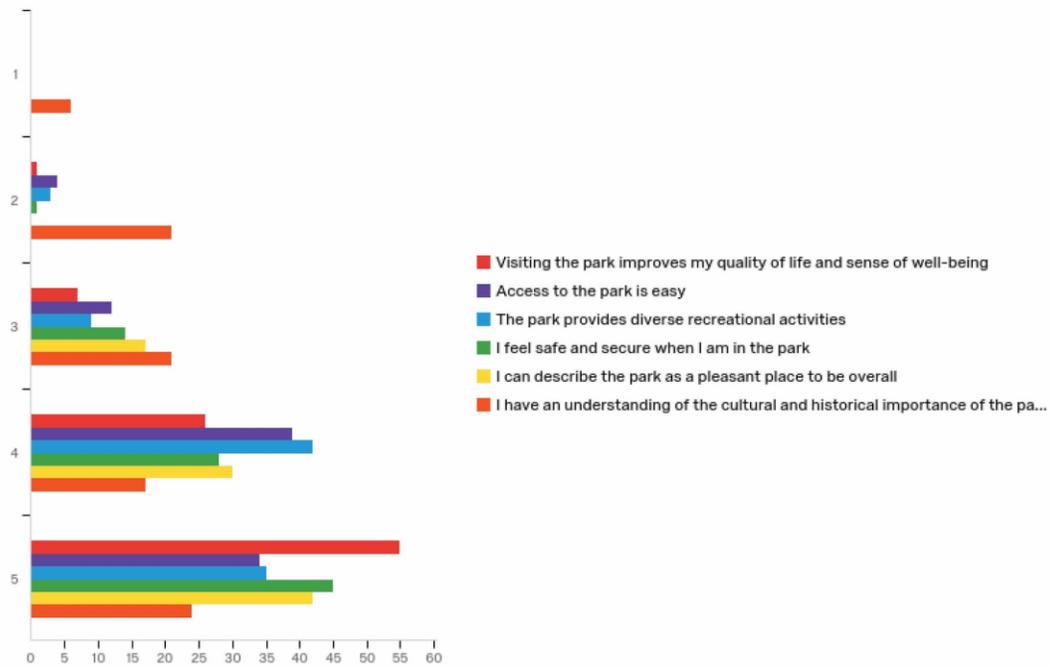
Q12 - How often do you visit nearby businesses/restaurants as part of your visit to the park?



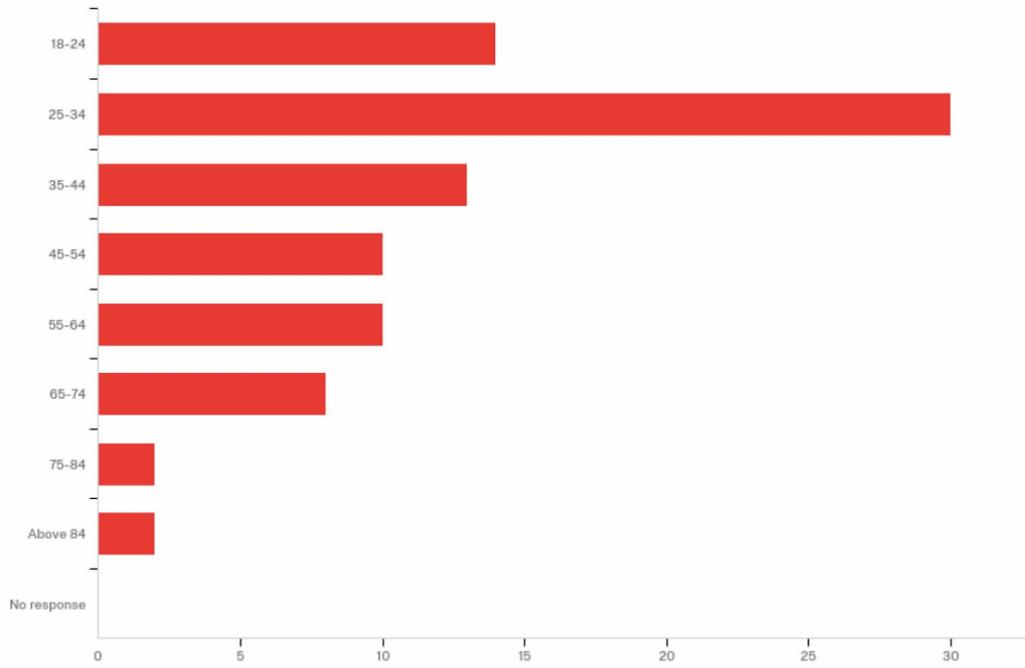
Q13 - Have you noticed a decrease in physical ailments such as, stress, asthma, and/or general poor health since you started coming to the park?



Q14#1 - Could you rate the following statements regarding your experience with Buffalo Bayou Park? (1 is... - Ranking



QID21 - What is your age?



QID24 - Are you of Hispanic, Latino, or Spanish origin?

