chapter three

natural & built environment

CHAPTER 3:

NATURAL & BUILT ENVIRONMENT

Photo by the Office of James Burnett

Our Situation

Since Oklahoma City's founding, the built environment has blanketed one of our most important yet finite natural resources: land. The metro's sprawling urbanized area continues to expand the interface between the natural and built environment and contributes to extreme heat, flooding, and water quality issues.

In *Natural and Built Environment*, we propose actions that will enhance our continued growth with development that fosters healthy ecological relationships, better protects water resources, and preserves and expands vegetative cover.

As illustrated in **Figure NB-1**, Oklahoma City's population growth from 1891 to 1960 produced the most densely-populated environment the city has ever experienced with more people per square mile (8,396) in 1950 than 2016 Los Angeles (8,362). City leaders expanded the city limits by 125% (360 square miles) in the following five years to accommodate this rapid population growth and the mass production of automobiles.

This expansion of city boundaries set the scene for sprawling development patterns that gradually replaced our natural environment with the built environment and established a precedent for impervious infrastructure growth over the next several decades. Impervious elements of the built environment, like roadways, buildings, and parking lots, absorb the sun's thermal energy and affect how precipitation moves once it reaches the ground. This changes how the natural environment behaves during extreme heat and inundating rainfall that creates the conditions for flash flooding, degraded water quality, and the urban heat island (UHI) effect.

The UHI effect is a phenomenon where an "island" of ambient heat causes significantly higher temperatures in urban areas compared to nearby rural areas due to the vast amount of buildings, pavement, and infrastructure. This concentrated heat increases electricity consumption and associated costs, contributes to poor air quality, and creates dangerous conditions for sensitive populations like the elderly and those who suffer from respiratory illnesses.

In recent years, the trajectory of development continued to increase with more than 124 million square feet of newly developed and redeveloped building space constructed between 2012 and 2016. As of 2017, Oklahoma City's urbanized area spanned more than 234 square miles covering 38% of the city.

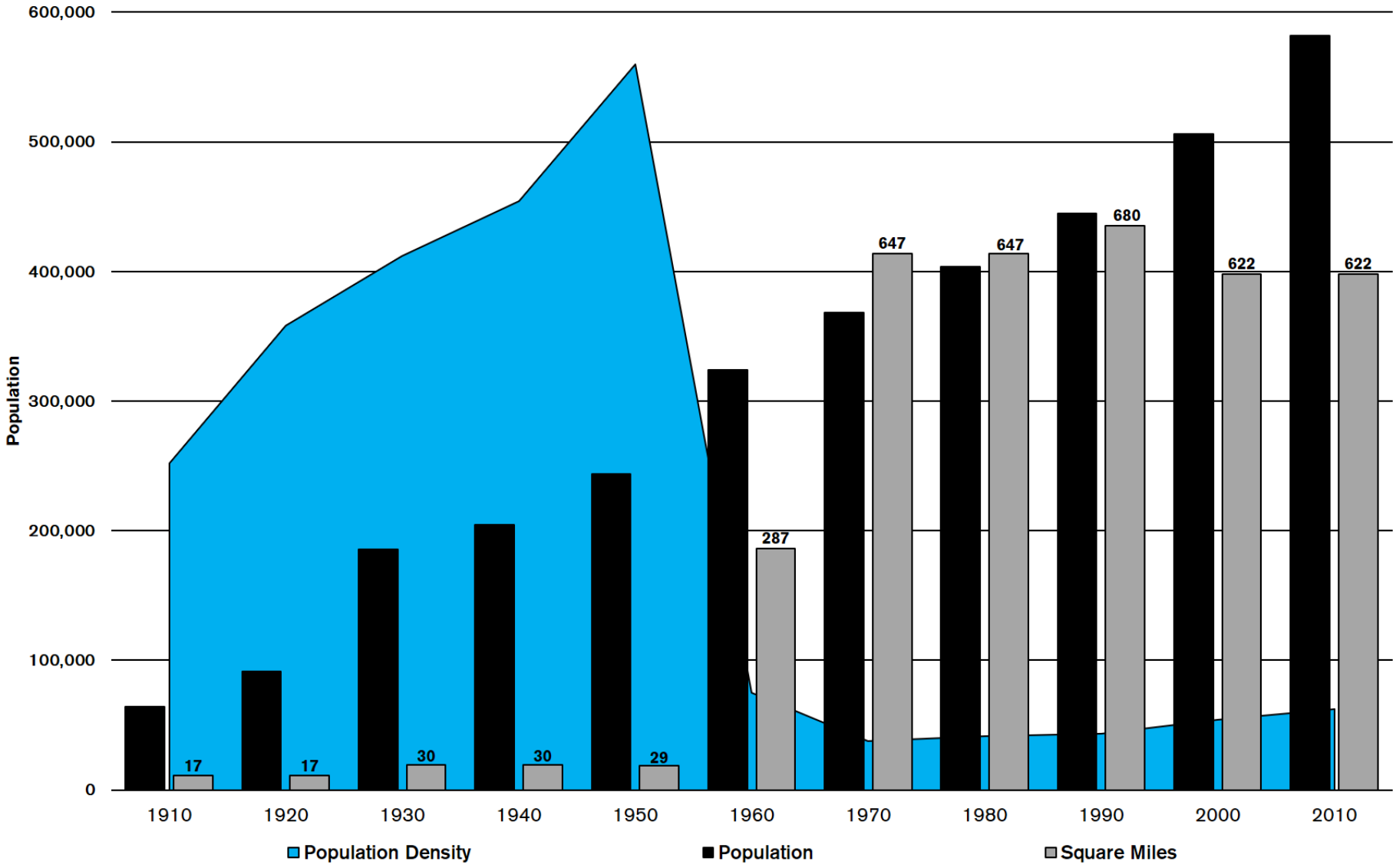
Boosted by code-required parking minimums, 11% of Oklahoma City's urbanized area is covered by the largest single type of impervious surface in the urban area: parking lots. Of Oklahoma City's entire 621 square mile area, four percent is parking lots – double the surface area covered by bodies of water.

Urbanization is synonymous with growth and growth is required to ensure our economic vitality. The question is not if we should grow, but how we grow. Sprawling development stretches demand and increases the cost of City services and, coupled with a changing natural environment and more severe extreme weather conditions, increases risk.

We must sustainably accommodate growth and maintain high-quality basic services while not degrading water resources or exacerbating the effects of extreme heat and associated costs. Development can merge form and function in a way that weaves the natural into the built environment, mitigating the negative impacts to water quality and public health by minimizing surfaces where heat is absorbed and water cannot infiltrate.

To this end, the City should institutionalize low-impact development (LID) techniques in capital improvement projects and allow and encourage LID best practices in private developments.

Figure NB-1: Oklahoma City Growth in Land Area, Population, and Density, 1910 - 2010



The chart above illustrates the dramatic rise and fall of Oklahoma City's population density. Since 1910, Oklahoma City's population has steadily increased, underscored by adding more than 80,000 people from 1950 to 1960. This influx of new residents into already tight confines caused city leaders to subsequently add nearly 400 square miles to the city's area in the 1960s to accommodate our rapid growth rate. After peaking in 1950 with more than 8,300 people per square mile (ppsm) and dropping to fewer than 600 ppsm in 1970, Oklahoma City's population density had only climbed to an estimated 1,036 ppsm in 2017.

Photo by Nick Oxford, Associated Press, 2013

LEFT: FLOODING IN MESTA PARK

The evening of May 31, 2013 saw approximately 8" of rainfall drench Oklahoma City in the span of about three hours, part of a severe storm that included an EF-5-rated tornado with a width of at least 2.6 miles. The torrential rain caused flash flooding and river flooding across the region with reports of at least one high water rescue performed at SW 86th Street and South Western Avenue. The flooding proved to be the deadliest on record for Oklahoma City. Lieutenant Jay Barnett of the Oklahoma City Police Department told *The Oklahoman* "Areas of the city that don't normally flood — we're seeing flooding."

Impervious Surfaces

A 2014 Climate Central report compared high temperatures in urban and rural environments to assess the impact of the built environment on heat levels. In Oklahoma City, we experience hotter temperatures by up to 15°F and approximately 22 more days above 90°F each year than nearby rural areas. The report attributes this heat disparity to urbanization that increases absorption of thermal energy. These extreme conditions can cause major issues for infrastructure, water quality, and public health.

Between July 1996 and September 2016, the National Centers for Environmental Information identified 32 extreme heat events that affected Oklahoma City resulting in 38 deaths and 326 injuries directly related to extreme heat. The fourth National Climate Assessment, released in November 2017, asserts the annual average temperature over the contiguous United States is projected to rise. The assessment also projects that a warming atmosphere will continue to increase extreme precipitation beyond observed increases across the country. Recent record-setting years may become the "new normal" in the next few decades with increases of about 2.5°F projected for the period of 2021 to 2050 relative to 1976 to 2005.

Localized projections from the *Climate in the Heartland* report project Oklahoma City's total annual precipitation will remain about the same over the next 30 years, but shorter, heavy rainfall events in the spring and summer are expected to increase. Oklahoma City residents can expect longer dry periods during hotter summers and shorter bursts of heavy rainfall and damaging flash flooding events.

A historic rain event in May 2013 that became the deadliest in Oklahoma City's history and the deadliest in the state since 1984 gave a glimpse of the dangers of increases in flash flooding severity and frequency. Over the course of a single day, 8" to 11" of rain fell on Oklahoma City. Emergency response personnel were dispatched on 114 separate calls of flood rescue and flood assistance. The storm ultimately resulted in an estimated $17 million in damage to Oklahoma City infrastructure and 13 fatalities.

Consistent, saturating precipitation can bring relief to drought-stricken areas, particularly those dependent on raising livestock and crops. Unfortunately, this type of weather pattern is expected to decrease. In its place, short windows of heavy rainfall will often provide more damage than benefit, and create hazardous conditions. If the ground is too dry, rainfall will move rapidly across the surface, washing away nutrients and evaporating before reaching deep plant roots. Excessive rainfall with saturated soil can remove oxygen from the soil. If the soil is too saturated before rainfall, runoff can cause roadways to flood and become impassable.

Drought conditions that drop reservoirs several feet below normal also cause higher concentrations of bacteria and organic matter that contribute to poor water quality. Warmer air temperatures, more days of extremely high temperatures, and longer periods without rainfall will decrease reservoir levels and increase water temperatures. Warm, stagnant, sunlit water with excessive nutrients like nitrogen and phosphorous – largely a result of over-fertilized lawns – are ideal conditions for the formation of blue-green algae (BGA), blooms of which produce toxins that pose health risks if consumed or inhaled by people, pets, or livestock. Outbreaks of BGA, like those in 2011 and 2016, can also threaten the Oklahoma City tourism industry, which generates $158 million annually in state tax revenue and $84 million annually in local tax receipts.

Projections of Oklahoma City's rainfall indicate a modest increase in annual precipitation. The average amount of rainfall per year in Oklahoma City will add 1.4" from 2021 to 2050 with a smaller increase of 0.7" from 2051 to 2080. While that equates to just a 5.7% increase across those three 30-year periods, the projections do indicate an important change in the distribution of precipitation based on seasonality. Oklahoma City summers are projected to see a reduction of 5.3% in precipitation in conjunction with a 7% increase in temperature. Our springs see a 4.6% increase in precipitation between the first two 30-year periods but remain flat thereafter, all while spring temperatures jump 13.8%.

These precipitation projections indicate our springs and summers are likely to be hotter and drier, but with a slight increase in annual precipitation, the rainfall will shift to the fall and winter. Fall will see the largest increase in seasonal precipitation with a 17% increase, from 9.8" to 11.5" with winter increasing 10%. While both will see average annual temperature increases, too - 4.6% for fall and 14% for winter - the likelihood of wetter, warmer winters could reduce the threat of damaging ice storms. These percentage changes are indicators of so-called "inundation events" where significant portions of precipitation fall over a brief period of time, triggering flash flooding as well as river flooding and overtax existing storm water and drainage systems.

Aside from risk to life and property, such massive flooding events can have lingering environmental effects due to the likely contamination of flood waters from a myriad of hazardous substances.

Water Quality

Maintaining clean water in reservoirs, lakes, and streams is a necessity that involves all levels of government. Municipalities like Oklahoma City with substantial amounts of impervious surfaces face a greater challenge of both increased storm water runoff volume and velocity as rainfall rushes from higher elevations through the network of storm water infrastructure and finally into water bodies. Roads, bridges, parking lots, buildings, and other impervious infrastructure are transformative changes which alter the functions of the natural environment thereby affecting the livability of our urban places and threatening the quality of our water.

Photo by Paul Hellstern, The Oklahoman, 2012

ABOVE: SE 125th STREET

More than three inches of rain fell in Oklahoma City on March 19, 2012, knocking out power to 1,500 businesses and households. Flash flooding washed out SE 125th Street, a privately-owned gravel road in far southeastern Oklahoma City and stranded households on the dead-end street by cutting off access to Dobbs Road. The washed out segment of SE 125th Street sits in a 100-year floodplain connected to the nearby Wes Watkins Lake reservoir.

Storm water runoff from impervious surfaces travels faster than natural conditions overburdening storm water infrastructure and resulting in more erosion, more flash flooding, more sediment and contaminants entering surface waterbodies, and less aquifer recharge. Soil erosion can cause significant damage to public facilities like parks and trails, while additional contaminants change the hydrologic conditions of the receiving waterbodies.

By disrupting the natural percolation of water into the landscape, the urban environment can exacerbate the physical hazards of inundating rainfall events by flushing a variety of contaminants down storm drains. Increases in the frequency and severity of flash flooding events also increase concentrations of sediment and pollutants swept from impervious surfaces into creeks, streams, and drinking water supplies.

Unlike pollution originating from one specific source, such as discharges from an industrial facility or sewage treatment plant, contaminants from several different sources that are carried into waterbodies by

rainfall or snowmelt are referred to as nonpoint source (NPS) pollution. NPS pollution is much more difficult to manage as both paved surfaces and manicured landscapes can increase contaminant levels.

As most of the impervious surfaces in Oklahoma City are used by automobiles, they are inherently dirty, covered in contaminants like oil, metals, grease, and sediment. The first five to eight minutes or first inch of rainfall is referred to as the "first flush," when the highest concentrations of contaminants are swept off our roads, parking lots, lawns, and rooftops directly into storm drains and deposited in local creeks, streams, or other waterbodies.

Runoff from landscaping and lawns can also degrade water quality when home or business owners apply excess fertilizers, herbicides, and pesticides. Bacteria and nutrients from livestock, pet waste, and faulty septic systems also contribute to NPS pollution.

As of 2016, 53% of the total area of Oklahoma City waterbodies was listed as impaired or threatened by at least one pollutant. The specific pollutants include high turbidity (a measure of total suspended solids or cloudiness of the water), dissolved oxygen, bacteria, oil and grease, nitrates, pathogens like enterococci and E. coli, selenium, mercury, chlorpyrifos, and chlorophyll-a.

A waterbody significantly impaired by a contaminant can trigger a time and resource intensive remediation planning process involving state and federal authorities. The Oklahoma Department of Environmental Quality (ODEQ) regulates point source discharges through review, permitting, licensing, and monitoring. If a waterbody is deemed threatened or impaired, ODEQ includes it in the state's list of impaired waterbodies, also referred to as the 303(d) list.

The 303(d) list is named for a section of the 1972 Clean Water Act which requires states identify waters that do not or are not expected to meet applicable Water Quality Standards with technology-based controls alone. States are required to establish a priority ranking for these waters, taking into account the pollution severity and designated uses of the waters. During this process, bodies designated Category Five are considered sufficiently impaired to warrant state development of a Total Maximum Daily Loads (TMDLs) which must document the nature of the water quality impairment, determine the maximum amount of a pollutant which can be discharged and still meet standards, and identify allowable loads from the contributing sources.

These TMDLs are calculations of the maximum amount of a pollutant allowed to enter a waterbody to meet water quality standards and are submitted to the EPA for approval and, if approved, state and local officials target reductions from point and nonpoint sources through an implementation plan.

Across Oklahoma, the most recent assessment based on 2016 data found 126 lakes and 550 rivers or streams were found to be classified as Category Five impaired: 520,967 acres of lakes and 8,747 miles of rivers and streams.

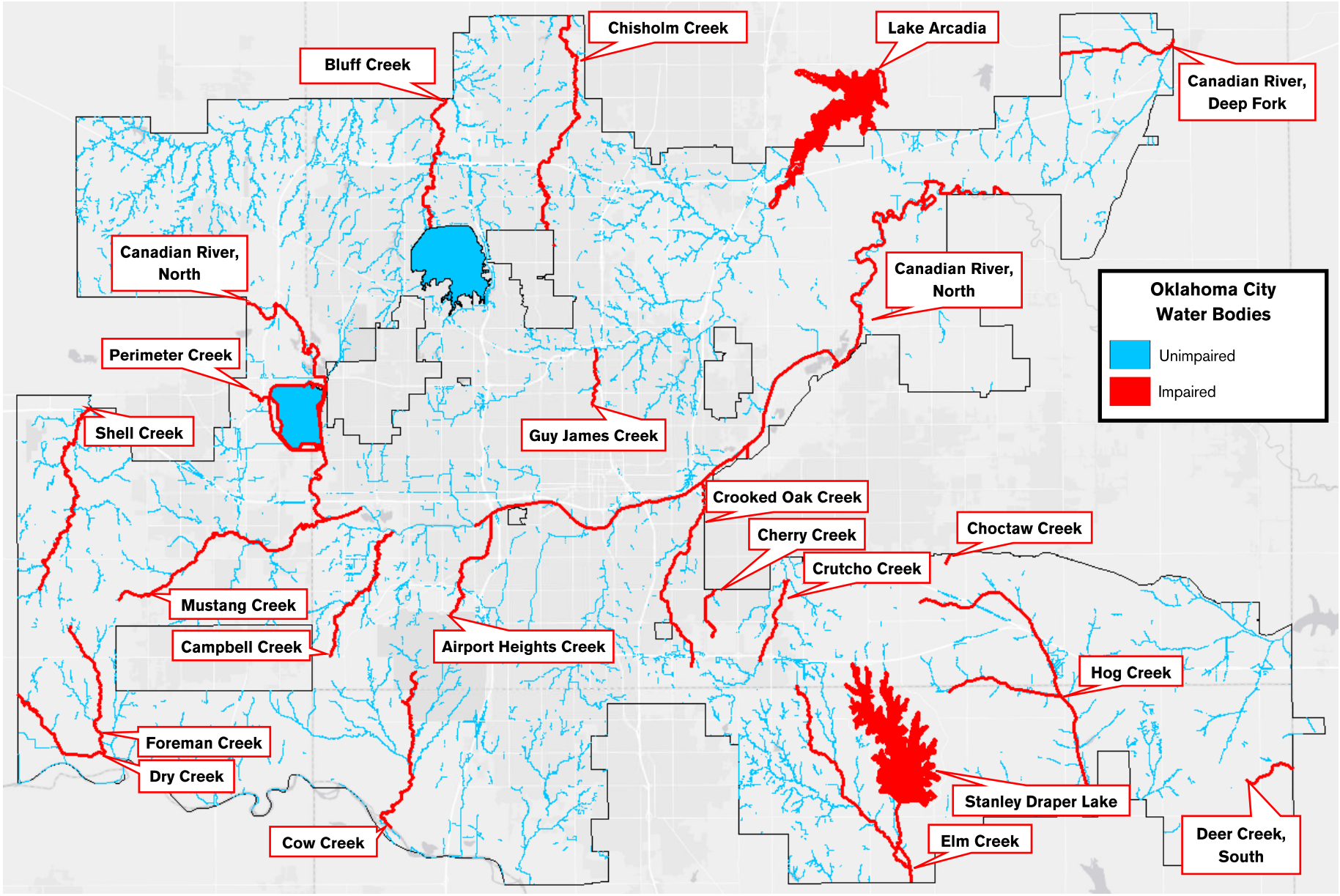
Impairment can lead communities to move towards higher stormwater utility costs to account for the greater capital needed to manage stormwater and this can include regulations on development within a watershed. Proactively seeking to limit stormwater runoff that contributes to impairment designation can be a strategic means of avoiding future costs that could hinder economic development or require greater fees.

Photo by Brent Fuchs, the Journal Record, 2016

ABOVE: LAKE STANLEY DRAPER WATER TREATMENT PLANT

Located in southeastern Oklahoma City, the Draper Plant has a water treatment capacity of 150 million gallons per day. Pollution from runoff can increase costs associated with treating drinking water.

Figure NB-2: EPA 303(d) Impaired Oklahoma City Bodies of Water, 2016



Source: U.S. EPA, Oklahoma Department of Environmental Quality

Urban Heat Island

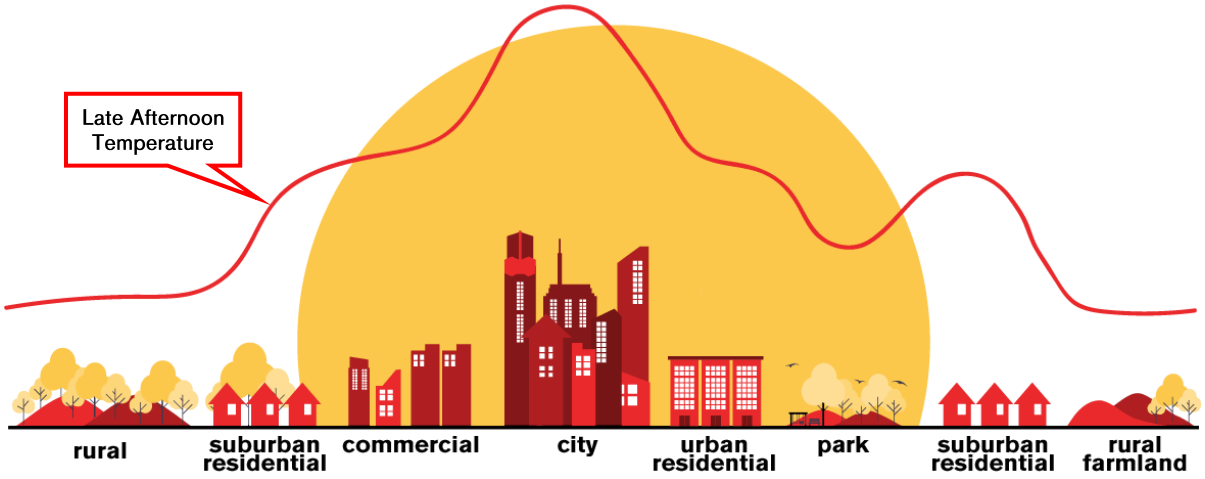
In addition to contributing to flash flooding and stream pollution, impervious surfaces such as streets, rooftops, and parking lots also absorb and store thermal energy as steel, stone, asphalt, and concrete reflect very little incoming solar radiation. These materials have very low albedo, or reflectance, and have a high heat storage capacity and are particularly common in densely-developed urban areas. This stored heat is retained in the material and gradually released, increasing ambient air temperatures and producing higher temperatures than those of less-dense, more vegetated rural areas (**Figure NB-3**).

This creates an urban heat island (UHI) effect where urbanized areas can store twice the heat of rural areas during the daytime, causing significantly higher temperatures, and creating "islands" of ambient heat over downtowns and suburban areas. A 2003 study comparing the UHI effect in Oklahoma City to Xi'an City, China concluded that population density, building density, and city size are important factors in UHI effect intensity. Additionally, less soil moisture and less vegetation cover over urban regions lead to surface warming since all absorbed solar radiation heats up the surface. Anthropogenic sources of heat such as energy consumption or vehicle exhaust contribute to the UHI effect as well.

A significant factor of the UHI effect is that it is not limited to daytime hours. Rather, materials radiate heat into the nighttime hours, ensuring that urbanized areas consistently sustain hotter temperatures. In Oklahoma City, there have been more frequent warm nights with five of the top 10 highest average minimum summer temperatures occurring in the last decade. Between 2004 and 2014, average summer overnight temperatures were more than 4°F hotter in cities than surrounding rural areas per a Climate Central research report.

There are multiple ways to capture and model the UHI effect. It is important we better understand Oklahoma City's UHI as we can deploy methods to combat its effects from an expanded urban tree canopy to requirements for high reflectivity on large urban and suburban roofs.

Figure NB-3: Urban Heat Island Effect



Increased daytime temperatures, reduced nighttime cooling, and higher air pollution levels associated with urban heat islands can affect human health by contributing to general discomfort, respiratory difficulties, heat cramps and exhaustion, non-fatal heat stroke, and heat-related mortality.

Health Impacts and Mortality. Extreme heat kills approximately 400 people each year and contributes to another 200 deaths in the U.S. The National Weather Service reports more deaths from heat in the past 30 years than any other type of weather including tornadoes, lightning, or floods.

The summer of 2011 was Oklahoma City's hottest summer on record with an average temperature of 87.5°F; the prolonged heat wave included a record of 43-consecutive days equal to or above 95°F as well as 21 non-consecutive days at or above 105°F. The Oklahoma Office of the Chief Medical Examiner identified 33 heat-related deaths in Oklahoma from May to September 2011 with the deceased ranging in age from 3 to 91 years and an average age of 52 years.

The UHI effect exacerbates respiratory sensitivities particularly for those with a higher risk of heat-related harm and death, including those over the age of 65, under the age of 4, in poverty, who are homeless, or who suffer from mental or physical disabilities. Additionally, the heat can increase air pollution as warmer ambient air temperatures during hot, windless days creates ideal conditions for the chemical reactions needed for the formation of ground-level ozone.

Formed when oxides of nitrogen (NOx) and volatile organic compounds (VOCs) chemically react in the presence of heat and sunlight, ground-level ozone is better known simply as smog. This is cause for concern given Oklahoma County's third-highest cause of death between 2011 and 2015 was bronchitis/emphysema/asthma, which the presence of ground-level ozone can exacerbate.

A 2014 report by Climate Central found a statistically significant correlation between higher daily summer temperatures and ground-level ozone concentrations in all 51 U.S. cities it studied. Urban areas are particularly susceptible to smog formation as there are typically higher concentrations of NOx and VOC emissions from personal vehicles and higher ambient air temperatures exacerbated by the UHI effect.

Photo by Paul Hellstern, The Oklahoman, 2012

LEFT: LINCOLN BOULEVARD HEAT DAMAGE

In July 2011, amid Oklahoma City's 28th day of 100-plus degree heat, the intersection of Lincoln Boulevard and NE 36th Street north of the Oklahoma State Capitol required repair after buckling. Lincoln Boulevard, a six-lane street, is more prone than streets of fewer lanes as the quantity of concrete increases the amount of thermal expansion.

Infrastructure. High temperatures, particularly long periods of extreme heat, can compromise the integrity of street, road, and highway pavements by softening asphalt and making it susceptible to rutting deformation. Concrete roads are also susceptible to buckling due to extreme heat as concrete panels absorb heat and expand, damaging the joints between panels and resulting in cracks.

Analysis conducted by the RAND Corporation in 2016 indicated Oklahoma is among the regions of the U.S. containing infrastructure projected to be disproportionately exposed to two or more weather hazards of higher intensity. While temperature impacts asphalt and concrete differently, climate factors such as precipitation, sunlight radiation, and freeze-thaw cycles affect the cost and efficiency of construction and maintenance as well as the useful life of the infrastructure itself.

As interstate highways have the most potential to be affected by drought, wildfire, and extreme temperatures, statewide cases of transportation infrastructure damage due to extreme heat are numerous.

Tree Canopy. Oklahoma City's tree canopy is a community asset that can help mitigate the urban heat island effect, reduce storm water drainage challenges, reduce heating and cooling costs, and improve air quality. Trees offer tremendous benefits for people and businesses in urban areas – shading hot parking lots and sidewalks, capturing storm water, capturing air pollution, and even providing a boost for business.

A human behavior study conducted by the University of Washington found shoppers were willing to pay 9% to 12% more for goods in tree-lined business districts than in shopping areas without trees.

The Oklahoma City Community Foundation (OCCF) and the Oklahoma Forestry Services (OFS) funded a tree inventory for the City of Oklahoma City Parks Department to translate into economic terms the environmental services provided by our trees and to support proactive tree care. The inventory project collected data from 19,632 trees that provide 310 acres of canopy cover in 134 City parks. The report calculated an estimated worth of $42.1 million, or $2,146 per tree, and provide more than $160,000 in air quality and storm water benefits annually. This project establishes baseline data to more efficiently plan for tree maintenance, plantings and replacements, and to protect tree canopy against potential threats like insects, disease, drought, ice and other severe weather.

In 2019, OCCF partnered with the Association of Central Oklahoma Governments (ACOG) and OFS to commission the Oklahoma City Metropolitan Area Tree Canopy Assessment over a 536-square-mile study area in the metro area. The assessment found nearly 65 million trees in the that are providing nearly $150 million in environmental benefits. The final report and accompanying geocoded maps illustrate how trees provide community-wide environmental, functional, and aesthetical benefits.

The data made available through these studies will shape our community's approach to air quality, extreme heat, and stormwater runoff planning, as well as inform optimal locations and tree types for future planting.

Flooding. Increases in heavy rainfall, flooding events, and population place greater emphasis on policy recommendations to reduce the amount of impervious surface required or allowed in development projects and determine what kind of water-conscious development options are possible. Oklahoma City has historically allowed development in the 100-year flood plain – the area with a 1% chance of flooding each year. Given projections of likelier inundation events in Oklahoma City, focusing resources on protecting assets in areas already prone to flooding will help avoid major losses and disruptions in the future.

Any development within a flood zone requires a permit. This includes, but is not limited to any and all new construction, filling, grading, and paving. Substantially damaged or improved structures, where the cost of repair or improvements equals or exceeds 50% of the building's market value, also requires building permits and elevation certificates, and are held to the same standards as new construction. Per FEMA, all new construction and substantially improved structures must be built at a minimum of one foot above the floodplain's base flood elevation. This standard provides added protection to structures but does not eliminate the flooding threat. Without these provisions, subsidized flood insurance through FEMA's National Flood Insurance Program would not be available to Oklahoma City property owners.

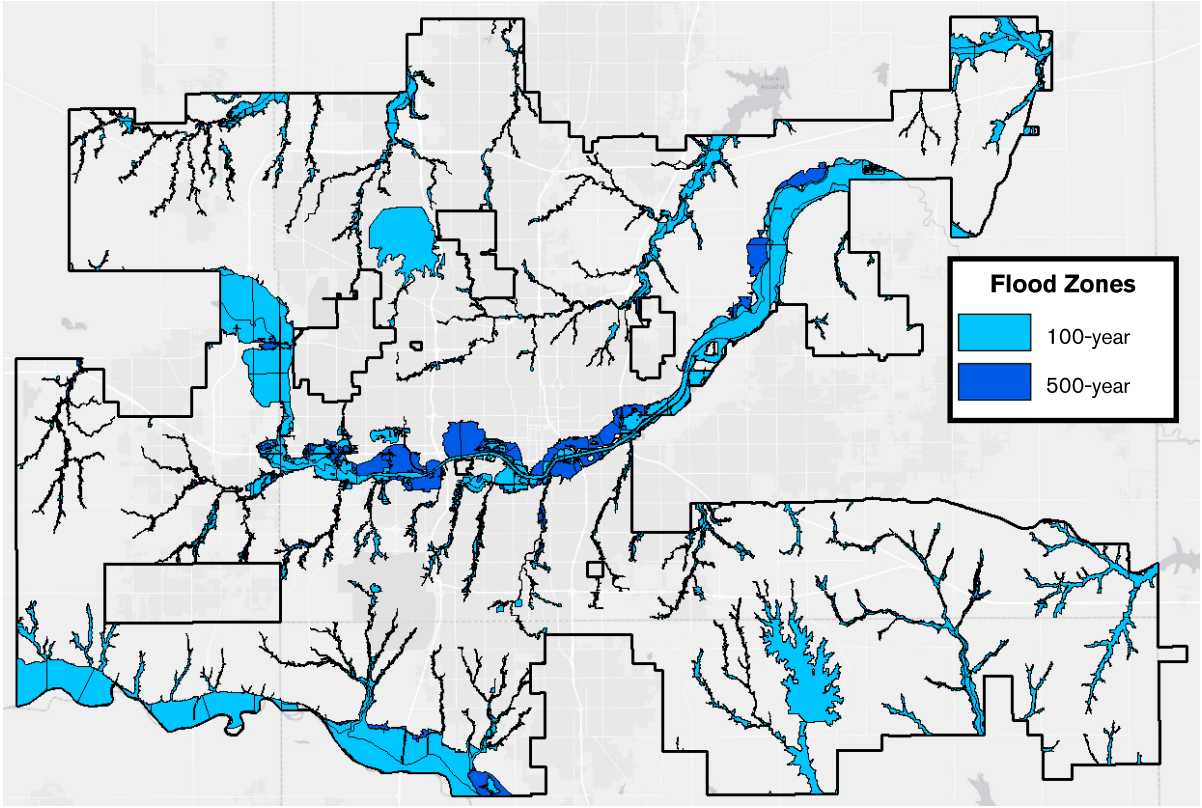
Currently, about 4,700 buildings are located within 100-year flood plains, occupied by more than 10,000 Oklahoma City residents. For perspective, a 500-year rainfall event in Oklahoma City would mean at least 5.2 inches of rain in the span of an hour, 12.5 inches of rain in 24 hours, 14.8 inches of rain in three days, or 15.5 inches of rain in seven days according to a report prepared by the U.S. Geological Survey. Oklahoma City residents have experienced several storms of that scale in recent history.

A 500-year storm event in June 2010 that brought more than 12" of rain in less than 24 hours damaged 209 structures in Oklahoma City and caused an estimated $5.5 million in damage in Oklahoma County. Three years later in May 2013, eleven people died in flood waters resulting from a heavy thunderstorm with tornadoes and large hail.

Flash flooding events also directly impact infrastructure even after the waters dissipate. Thirty days of rainfall in May and June of 2015, which included two 500-year flood events, resulted in Oklahoma City experiencing more than 24" of total precipitation, having a "significant impact on Oklahoma City roads." *The Oklahoman* reported rainfall on Saturday, May 23rd alone "caused evacuations, damage and severe flooding" that produced impassable intersections, multiple road closures, and even sinkholes.

Retrofits of and expansions to our existing drainage system are costly but no doubt necessary. Traditional storm water controls have focused almost exclusively on reducing pollution without addressing the increased volume of storm water discharged from urbanized areas. The benefits gained from removing pollutants are often overshadowed by the magnitude of the runoff volume. Even with storm water controls and high rates of pollutant removal, without volume reductions urban areas will contribute more pollution than pre-development conditions - thereby making it difficult to achieve important federal water quality standards.

Figure NB-4: Oklahoma City Flood Zones



ABOVE: Map of Oklahoma City's 100-year and 500-year flood zones. Approximately 111 square miles (18%) of Oklahoma City's land area is in a flood zone.

Low-Impact Development

Low-impact development (LID) is an approach to development that includes holistic site design utilizing green infrastructure treatments to divert storm water into natural areas on a site rather than directly into streets and storm drains. This approach allows design flexibility and can incorporate a variety of practices that ultimately prioritize rain water retention and groundwater recharge over runoff into storm drains or ditches which can cause or worsen urban flooding and pollution transmission.

Green infrastructure (GI) is an umbrella term for networks of natural ecosystem and greenway corridors as well as engineered-as-natural storm water management elements designed to blur the contrast between the natural and built environment. Incorporating both natural and engineered solutions, GI elements in storm water management seek to mimic the natural water cycle that protects and restores a variety of habitats. Green roofs, porous pavement, swales and rain gardens are examples of GI that are also LID practices; these treatments largely rely on using soil and vegetation to infiltrate, evapotranspirate, and/or capture storm water runoff and reduce flows to drainage collection systems.

By emphasizing infiltration, LID techniques allow rainwater to filter through soil before being slowly released to streams. This natural, but deliberate storm water management can help prevent negative impacts of flash flooding events, such as dispersing too much sediment into local creeks and stream habitats, road damage or closures, and/or loss of private property.

Incorporating LID features can increase property values and provide an opportunity to add an aesthetic local context to a community. What could have been a series of pipes, outfalls, concrete channels, and fenced basins plunging rainwater downstream is instead a thoughtfully-designed landscape of native plants and pollinator habitats holding and actively filtering storm water.

In Norman, the Trailwoods neighborhood was developed with an intent to study the effect LID treatments like green infrastructure can have on pollutant concentrations in storm water runoff that would ultimately end up in Lake Thunderbird. The neighborhood was designed with 17 homes that featured conventional "curb-and-gutter" storm water management practices and 17 homes designed with a variety of best management practices (BMPs) like porous concrete, rain gardens, rain barrels, and downspouts that divert and capture rainwater.

The EPA awarded a $500,000 monitoring grant to the University of Oklahoma and the results of the study highlighted a noticeable difference between the development approaches. The LID half of the development saw a nitrogen reduction of 30%, suspended sediment reduction of 32%, and a 152% reduction in phosphorous compared to the conventional side.

Example LID Projects

Blake-Service Soccer Complex
Edmond, Oklahoma

The City of Edmond installed a $38,000, 200-foot long rain garden to capture runoff from the complex's parking lot to filter stormwater before it is discharged into nearby Arcadia Lake.

Guthrie Green
Tulsa, Oklahoma

The 2.2 acre downtown green space, a remediated brownfield, includes bioswales to collect surface runoff and rooftop runoff and remove silt and small trash before it reaches the City's stormwater system.

Greening America's Communities

In 2016, Oklahoma City was awarded a technical assistance award from U.S. EPA under the Greening America's Communities Program to address flooding and connectivity issues for five key locations including the Paseo Arts District, Central Park, Jefferson Park, and Edgemere Park neighborhoods. City staff wanted design concepts that would capitalize on opportunities to integrate green storm water management with street and public space improvements that would support better environmental conditions downstream. EPA brought together a team of federal agency staff and design professionals to help the City create community-supported design solutions for each key area.

Engaging with neighbors and business owners from the project area offered the opportunity for the design team to learn the detailed history of flash flooding events and how residents' perception of and interaction with Guy James Creek has changed over time. Many residents expressed a desire for the design concepts to enhance quality of life, but in a way that preserves both historic character and natural spaces.

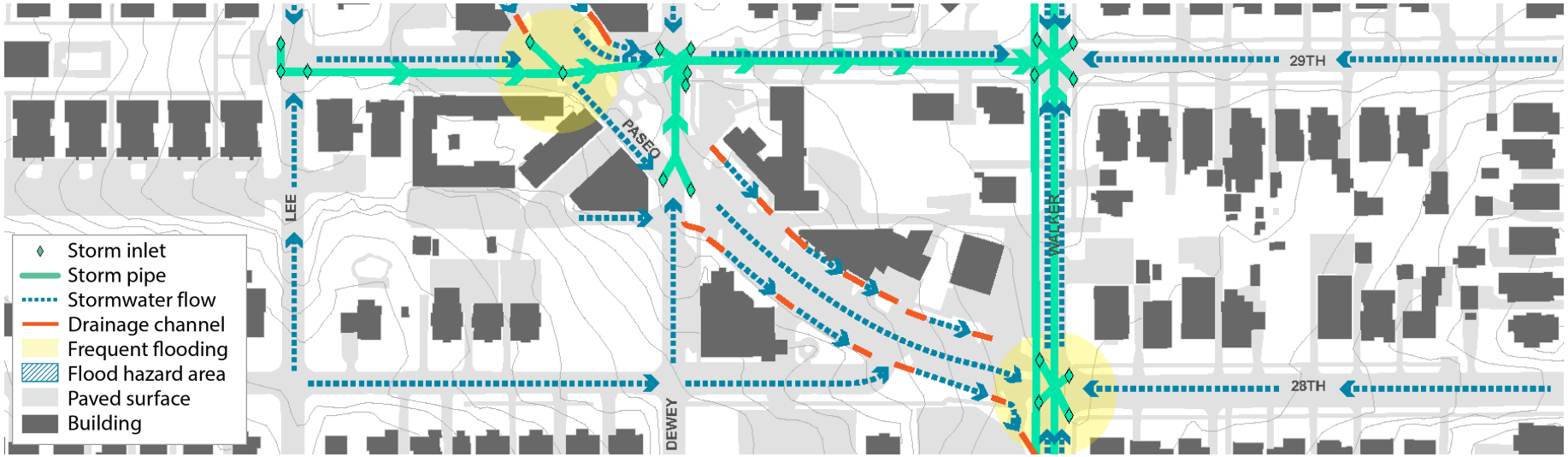
The resulting report provided community-driven concepts to the City that can serve as a starting point for potential future projects. The concepts incorporate a variety of green infrastructure tools to address storm water runoff with public amenities that improve connectivity and reduce pedestrian-cyclist conflicts with automobile traffic.

On Sept. 12, 2017, Oklahoma City voters approved 13 bond propositions and two sales tax initiatives known as the Better Streets, Safer City projects. Paseo Drive and Walker Avenue were included in the $240 million list of projects for new streetscapes which could include LID elements.

LEFT: EDGEMERE PARK

Edgemere Park Historic District, one of the first planned communities west of the Mississippi River, is characterized by mid-sized to large, well -maintained homes looking out toward Edgemere Park and Guy James Creek, a tributary of the Deep Fork River. Stream banks are highly eroded in some areas and the stream is deeply incised, creating steep drops from the surrounding park lawn.

The design concept for Guy James Creek, pictured left, increases the size of the creek to hold more storm water, and stabilizes the banks with plantings to reduce erosion; two outfalls shown in this illustration control water flow and a path connects visitors to the creek edge.



ABOVE: CONCEPTUAL PASEO DRIVE/NW 28th STREET AND WALKER AVENUE INTERSECTION ILLUSTRATIONS

The Greening America's Communities report identifies this wide intersection (above, left) as an important entry into the Paseo District, but notes frequent floods and north-south vehicles speeding on Walker Avenue. The intersection lacks pedestrian crossings, and the sidewalks are in disrepair. A proposed recessed roundabout (above, right) slows vehicles moving through the intersection and captures storm water during rain events. New sidewalks and street markings improve pedestrian safety, dedicated bike lane address cyclist safety, and planted bump-outs collect and infiltrate additional street runoff. The map (above, center) charts drainage infrastructure, topography, and areas of flooding from an aerial perspective.

Food Access

Across the country, the role of local government in the availability of and access to fresh, healthy food continues to gain prominence. One of the many factors contributing to this increased prominence is the importance of food to public health, especially as the adult obesity rate in the U.S. population exceeds 35%. Oklahoma is one of six states where 35% or more of the population is considered obese. The Oklahoma City metro saw a 20% increase in adult obesity between 2011 and 2017 according to the Center for Disease Control's Behavior Risk Factor Surveillance System.

Food access is just one determinant of health, however, as it also intersects with broader factors of both public and private influence, from land use and transportation to affordability and income. Access to and availability of healthy food is rooted in historical factors. Suburbanization, propped up by federal housing policies after World War II, caused significant population shifts from urban centers to sprawling new neighborhoods on the periphery - with grocery stores and supermarkets relocating accordingly. Today, revitalized urban centers are again hubs of population and commerce but struggle to attract those displaced supermarkets and grocery stores due in part to the cost and complexity of infill development in dense, historic downtowns.

Data from the Food Marketing Institute indicates grocery stores and supermarkets are trending smaller with a median square footage of 41,300 in 2016, down 15% from a peak of 48,750 square feet in 2006. While this gradual shift signals a broader move towards more dense grocery store and supermarket development, it also signals greater risk as the average supermarket in 2017 carried greater than 30,000 items. Research published in the *International Journal of Environmental Research and Public Health* that assessed grocery stores and supermarkets in Minnesota concluded "that smaller food stores have higher prices for most staple foods compared to their closest supermarket, regardless of proximity." Reductions in store square footage reduce inventory and can drive prices up, thereby contributing to low food access by limiting consumer buying power, particularly in low-income areas where access and/or inventory might already be constrained.

Retail food expenditures are the third largest U.S . consumer spending category at 12.6%, behind only housing and transportation. The U.S. Department of Agriculture's (USDA) most recent food expenditure data found in 2017 Americans spent an estimated $746 billion on food to be prepared and/or consumed at home. Almost 60% of this expenditure occurred at grocery stores followed by 22% at warehouse clubs and supercenters. Locally, food expenditures in FY19 generated an estimated $101 million in sales tax revenue for the City, with about $62 million of that generated from restaurants and about $22 million from supermarkets, grocery stores, and specialty food stores, followed by about $10 million from sales in gas stations and convenience stores. Total food expenditures for FY19 comprised approximately 22% of Oklahoma City's overall sales tax revenue.

Food Deserts. Census tracts where residents have limited access to affordable and nutritious food - usually understood to be fresh fruits, vegetables, and meats - are often described as food deserts. More specifically, the Food, Conservation, and Energy Act of 2008 defined food deserts as "an area in the United States with limited access to affordable and nutritious food, particularly such an area composed of predominantly lower-income neighborhoods and communities."

These areas are determined principally on proximity of households to supermarkets or grocery stores with additional variables of socioeconomic composition, vehicle ownership, and distance based on urban or rural development intensity. While USDA offers more than one food desert definition based on distance, the preferred approach to Oklahoma City food deserts identifies low-income census tracts where more than 100 housing units do not have a vehicle and are more than ½ mile from the nearest supermarket in an urban area. Inclusion of the vehicle ownership metric better reflects Oklahoma City's sprawl and development pattern.

The initial 2010 data found 27 Oklahoma City tracts were food deserts, representing a population of 92,633. By 2015, the number of food desert tracts increased to 31, affecting an estimated population of 98,591. Consistent with the body of literature on food access, in both 2010 and 2015 the residents of food desert tracts in Oklahoma City are overwhelmingly non-white - 52% and 56%, respectively. More specifically, the black and Native American populations in food desert tracts increased in those five years at a rate of about 21% and 17%. Those rates are even more highly disproportionate considering that from 2010 to 2015, the Black and Native American populations citywide increased just 7% and 3%. Research has consistently demonstrated how food deserts impact the health outcomes of low-income communities and have significant impact on communities of color. Between 2013 and 2017, the Kaiser Family Foundation analysis of the Centers for Disease Control and Prevention's Behavioral Risk Factor Surveillance System survey found that Black (74.7%), Hispanic (73.7%) and American Indian/ Alaska Native (77.3%) residents in Oklahoma have higher adult overweight and obesity rates than white residents (69.6%).

Food Swamps. An alternative but complementary perspective on food access emerged from 2009 research in post-Katrina New Orleans. The food desert concept stems from a perspective of undernutrition, as lack of access inhibits availability of fresh and healthy foods. The inverse is the "food swamp," as the researchers found areas of New Orleans where access to healthy foods was overwhelmed or "swamped out" by plentiful fast food restaurants and convenience stores.

Citywide parcel data from 2018 illustrates that of Oklahoma City's 290,318 residential units, greater than half (about 54%) are within a half-mile of a fast food restaurant alone. With at least 356 fast food restaurant parcels identified, that means each has an average of 443 residential units within a half-mile. Alternatively, only about 30% of residential units citywide are within a half-mile of a grocery store or supermarket. With such a saturation, determining what and how public policy could contend with consumer choices is daunting, even as Oklahoma City health outcomes grow increasingly poor.

Urban Agriculture. Another option to support access to healthy foods is to allow and encourage residents to grow, distribute, and sell their own, especially where public resources can be used to enhance self-sufficiency. A significant step to this end was taken by Oklahoma City in December 2013 with the adoption of the urban agriculture ordinance. This ordinance introduced to Oklahoma City's code legal definitions for aquaponics, hydroponics, and compost, and created new use units that enabled broader implementation of agriculture practices in urban settings including rainwater harvesting, roof gardens, urban farms, and community gardens. Perhaps most importantly, it codified the ability for residents to grow and maintain home gardens on the front, rear, and side yards of their property.

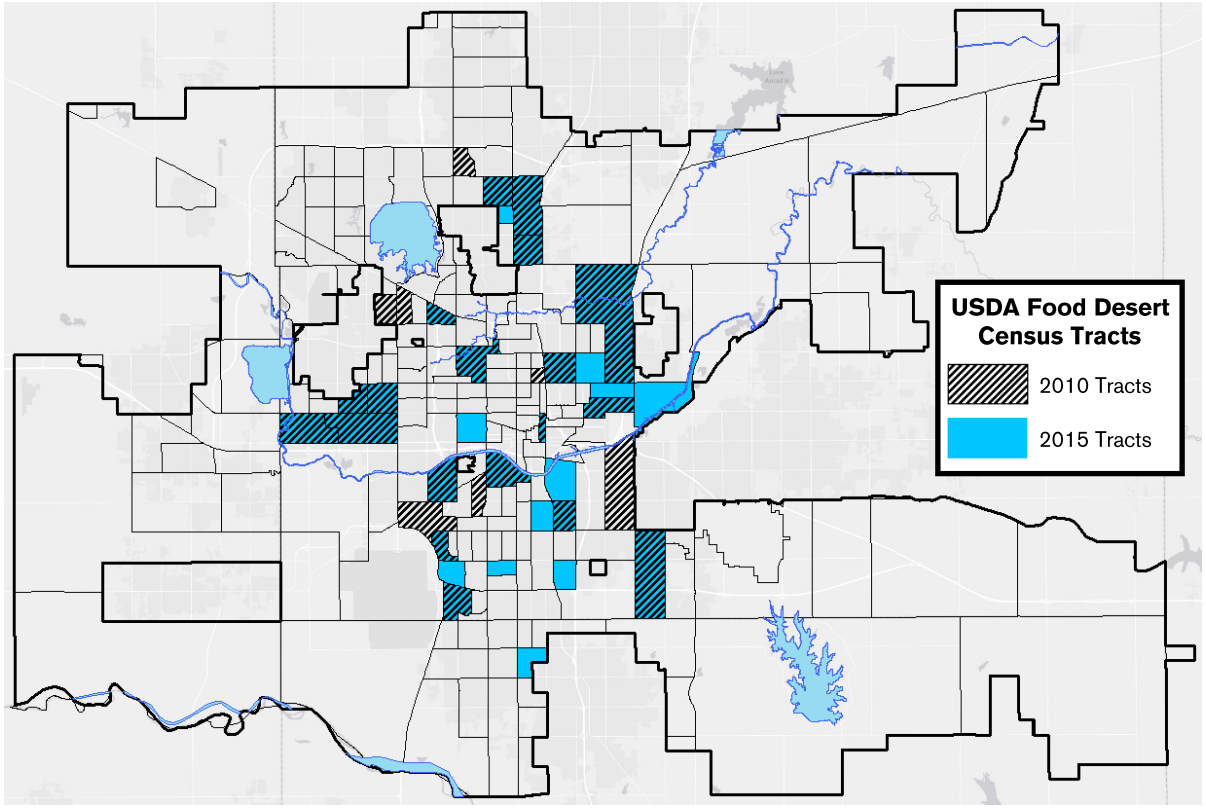
Sales of homegrown produce at or from a farm are exempt from sales tax per state law, but these sales are not permitted in residential areas by the ordinance. While the ordinance simply addressed what residents could or could not do on their property, urban agriculture program models elsewhere have leveraged public property to increase communitywide benefit and improve access to land, water, and tools necessary for vegetable growth.

In 2012, the City of Lawrence, Kansas launched a program called Common Ground which makes underutilized public property available to organizations for food production. These organizations must apply through the City of Lawrence and, if approved, become licensees who must follow policies and procedures that provide for safe and responsible use, similar to Oklahoma City's approach to maintenance agreements for medians with neighborhoods and private businesses.

At the close of 2018, the Common Ground program had nine program sites with 116 plots and four cooperative areas managed by 272 gardeners and volunteers, all of which resulted in more than 1,500 lbs. of produce donated in addition to two sites open to anyone in the community for harvest. Not only does this create space for community involvement, often set within pocket parks located inside neighborhoods, but it can reduce maintenance costs by using unoccupied space that might otherwise require mowing or the application of herbicide and pesticide.

There can be an economic component, too, to urban agriculture as locally-grown produce can be seen at any of the farmer's markets across the metro. Yet expanded opportunities for urban agriculture are still an interim step towards greater food access. More research and study is needed to determine what specific policy tools, from economic development to food cooperatives, could best work towards not only increasing food options, but also contributing to a healthier lifestyle that includes physical activity, a built environment conducive to aging-in-place, and fewer financial barriers. Many cities across the U.S. are struggling with how to resolve issues of food access but much of the results thus far indicate there is no panacea. Rather, there is a need for a holistic approach that more directly addresses root causes of food access and poverty.

Figure NB-5: Oklahoma City Food Desert Census Tracts, 2010 and 2015



Source: U.S. Department of Agriculture

Between 2010 and 2015, the number of food desert tracts increased by about 15% from 27 to 31 as well as the percentage of non-white residents in those areas (52% in 2010 to 56% in 2015).

Our Plan

For a modern city to remain globally competitive, it is critical to expand existing industries, attract new businesses, and accommodate more residents. Oklahoma City can distinguish itself by developing in a sustainable, efficient way as it grows that does not leave even greater challenges for future generations. Visitors and residents alike recognize the need to ensure local waterbodies are protected from contamination and vulnerable populations can find relief from the financial and physical effects of extreme heat.

Our plan seeks to ensure Oklahoma City realizes the benefits of the efficient growth pattern advanced by planokc, while encouraging proactive solutions to maintain a complimentary relationship between the natural and built environments. This complimentary relationship will strengthen the economy and sustain residents' high quality of life for many generations. Inaction addressing current and future vulnerabilities will affect our ability to deliver on existing commitments and lead to higher costs in the future.

By increasing tree and vegetation cover, making roofs and hardscapes cooler, and implementing the development and conservation strategies outlined in planokc, we can limit the negative impacts of urbanization on public health, local watersheds, and sustainable economic growth. Today's action (or inaction) will shape tomorrow's economic, social, and environmental vulnerabilities.

Our Goals

WATER QUALITY

1. **Protect water quality.**

FLOODING

2. **Prevent damage caused by flooding.**

URBAN HEAT ISLAND

3. **Mitigate effects of extreme heat.**

FOOD ACCESS

4. **Ensure residents have access to healthy food.**

Our Initiatives

Natural & Built Environment Initiatives	Goals 1	2	3	4
1. Use and promote low-impact development in City projects.	■		■	
2. Codify low-impact development policies and promote best practices for private development.	■		■	
3. Mitigate flooding vulnerabilities.		■		
4. Mitigate areas of high heat exposure.			■	
5. Support small-scale food production on vacant public land or underutilized park space.				■

"It should be indicated that urban development and environmental protection are not incompatible. With appropriate environmental criteria entering the land use management/ comprehensive planning process, there can be adequate quantities and rates of urban development as well as the preservation and protection of the natural environment."

- An Overview of the Natural Environment of Oklahoma City: Its Capacities and Limitations, 1976

INITIATIVE 1

STRATEGICALLY USE LOW-IMPACT DEVELOPMENT (LID) IN CITY PROJECTS

Develop a low-impact development implementation strategy for City projects. City-funded public projects are the most immediate opportunity to lead by example on LID. Be it through general obligation bond funds, an iteration of MAPS, or federally fund-supported programs and projects, the City can nurture and grow expertise in LID internally plus familiarize local and region architectural, engineering, and construction firms with LID practices.

POLICIES

NB-1: Provide LID training for City staff involved in design, review, inspection, and maintenance of LID systems.

NB-2: Initiate a multi-departmental process to develop an LID implementation strategy.

NB-3: Incorporate LID techniques developed in NB-2 in City projects and new facilities.

NB-4: Promote LID features at City facilities with signage and online map.

INITIATIVE 2

CODIFY LID POLICIES AND PROMOTE BEST PRACTICES FOR PRIVATE DEVELOPMENT

Establish design criteria for low-impact development techniques. While engineering standards and guidance are important, LID practices must be allowed to achieve drainage standards for development. The City should set standards for design and maintenance and encourage the use of LID by incorporating LID best practices.

Developers and property owners need clarity from the City to successfully implement LID practices. The City, too, needs to articulate standards to ensure, at minimum, LID is done correctly so as to ensure it functions successfully over time. This clarity must come in the form of formal policies such as new or updated ordinances as well as informal guidance to provide the greatest range of opportunity for those in the private sector to incorporate LID practices into their properties.

Create a low-impact development manual for architects, engineers, and developers. The Drainage Criteria Manual refers to a LID manual to guide landscape designers but one does not presently exist. Creating a LID manual would help remove perceived barriers to implementation of these practices.

Enhance the City's landscape ordinance. Developers and property owners are already bound to landscape requirements per the City's landscaping and screening regulations. The present landscape ordinance is a point-based system to afford flexibility to developers and property owners through a menu of options. Given the ordinance's purpose to "promote the enhancement of Oklahoma City's urban forest," expanding the ordinance's foundation and scope would be a strategic means both of improving development and mitigating heat.

Promote water quality programs, resources, and policies. The City's Storm Water Quality (SWQ) division of the Public Works department provides education and outreach about storm water quality and actively promotes programs like Curbs to Creek and concepts like LID. The Office of Sustainability can partner with SWQ to help boost the reach of water quality education.

Develop watershed master plans. LID practices often function to reduce runoff from localized impervious surfaces. Research has found LID planning on the scale of a watershed can identify high impact locations for LID intervention and, in doing so, inform cost-effective planning decisions for LID siting. A watershed-based planning approach could also help the City maximize use of public land such as parks, right-of-way, and City buildings to achieve water quality benefits.

POLICIES

NB-5: Create a low-impact development guide/manual for architects, engineers, developers, landscape architects, and planners.

NB-6: Increase promotion of water quality resources and programs, like Blue Thumb, on the City's website.

NB-7: Review and update list of nuisance vegetation and invasive species in municipal code.

NB-8: Inventory use of herbicides and pesticides in parks and other public properties, develop strategy, and establish targets to reduce use.

NB-9: Conduct ecological assessments and develop long-term management plans for watersheds.

Growth is inevitable and desirable, but destruction of community character is not. The question is not whether your part of the world is going to change. The question is how.

- Edward T. McMahon

INITIATIVE 3

MITIGATE FLOODING VULNERABILITIES

Collaborate to improve our Community Rating System (CRS) score. Under the National Flood Insurance Program's (NFIP's) CRS, flood insurance premium rates are discounted to reward community actions that reduce flood damage to insurable property, support the insurance aspects of the NFIP, and encourage a comprehensive approach to floodplain management. With approximately 112 sq. mi. of Oklahoma City (~18% of the city's area) designated as a floodplain or floodway, staff should collaborate between 5-year certifications to improve the city's CRS rating to increase affordability of flood insurance for residents.

Survey properties in vulnerable areas including flood plains. Identifying and receiving proper reimbursement for historic properties after severe weather events is challenging and sometimes impossible. Properties endangered by severe weather and flooding should be surveyed and documented prior to disaster events to better preserve our history and streamline the FEMA reimbursement process.

Discourage alterations to the 100-year flood plain. Alterations to flood plains can have negative effects on downstream, neighboring properties that can cause unexpected flooding. Enhancing requirements for developing in the 100-year flood plain – the area with a 1% chance of major flooding every year – will prevent loss of life and property and reduce the cost of recovery. FEMA's National Flood Insurance Program uses insurance discounts to incentivize specific flood plain management activities, such as preserving open space, discouraging development in certain areas, establishing clustering or setback rules, or encouraging green infrastructure or LID techniques in new development. Oklahoma City can pursue deeper insurance discounts for property owners by using projections rather than only historical data to inform regulatory maps.

Encourage resilient building practices in the 500 -year flood plain. Over time, flood risk shifts and changes, in part due to development, and maps are updated to reflect areas of high risk. As demonstrated by the three 500-year flood events Oklahoma City experienced over the course of five years, what was once a 100-year floodplain may turn into a 25-year floodplain due to increased frequency of inundating rainfall events or changes to nearby topography due to development.

Encouraging developers and property owners to plan for the life of the development will protect investments and prevent costly major losses from future catastrophic events.

POLICIES

NB-10: Work with Historic Preservation Office to map historic properties in areas vulnerable to flooding.

NB-11: Discourage alterations to the flood plain with 1% annual chance of flooding (100-year).

NB-12: Conduct historical flood damage assessment and inventory of properties in flood plains.

NB-13: Update municipal code to increase elevation requirements for new construction and substantially-improved structures in the 500-year floodplain.

INITIATIVE 4

MITIGATE AREAS OF HIGH HEAT EXPOSURE

Assess current tree canopy and set a coverage target. Tree inventories can be conducted in detail on the ground or at a high-level using aerial images and analysis software. Understanding first where the City's vegetative coverage gaps are, in addition to demographic data, will help prioritize mitigation activities to the most vulnerable areas.

Develop methods to measure, monitor, and report local urban heat island conditions. To develop the best efficacious and efficient mitigation policies, consistent and reliable data is a necessity.

ABOVE: KITCHEN LAKE

Part of the city's "Close to Home" fishing waters program, Kitchen Lake is a 33-acre lake stocked with largemouth bass, crappie, and three types of sunfish. Reducing pollution from stormwater runoff helps maintain healthy waters to benefit both aquatic life and casual anglers.

In the same way the quality of our water and air is monitored, we need a similar quantitative approach to our own urban heat island to understand and counteract its impacts.

Urban heat islands are multivariate and many factors, including seasonality, water usage, time of day, and climate influence their impacts. A robust incorporation of standard monitoring methodology should be the first step into integrating urban heat island effects into City decisions and, ultimately, policies.

Eliminate minimum parking requirements. Oklahoma City mandates the amount of surface parking required for new developments. This translates to added costs to developers, a reduction in developable land, and increased impervious surface that contributes to flooding and the urban heat island. The City should either default to parking maximums or, as has already been done with development in downtown, remove such requirements entirely and allow developers and their financiers to determine parking needs on a project-by-project basis.

Use highly reflective roofing materials when constructing new or replacing roofing on City facilities. Whether amidst a densely-developed area or surrounded by impervious surfaces, large roofs can be used to deter the intensity of urban heat islands. Whether new construction or retrofit, alternative roofs can reflect rather than absorb thermal radiation and thereby limit increases of ambient air temperature.

Such alternatives include light-colored, highly reflective materials or paint to boost albedo; vegetative or "living" roofs; planters to accommodate urban agriculture; or photovoltaic solar arrays.

Develop guidance for green roof installations. Green roofs provide both cooling and storm water benefits that will reduce pollution, electricity demand, and other effects of the urban heat island. Materials selection and proper installation is critical for a successful green roof. Standards and best management practices should be developed to maximize benefits, reduce maintenance costs, and streamline the review process.

Preserve trees and expand shade cover. Preserving mature trees is a vital step in realizing the ecological service and public health benefits now and in the future. Removing mature trees not only visibly alters the landscape, but can also drastically affect drainage and effects of the urban heat island. Activities on both public land should prohibit mature tree removal and private developments should be incentivized to preserve mature trees.

Vegetative cover and trees in particular will reduce the effects of the urban heat island and provide additional storm water and air quality benefits. Programs such as the Arbor Day Foundation's Energy-Saving Trees provide a platform for organizing tree-planting initiatives that assists property owners in siting prospective trees where they will block heat-gain from direct sunlight and maximize energy efficiency gains. Shade structures should be encouraged in areas where tree growth is not feasible.

POLICIES

NB-14: Determine methods to measure, monitor, and report local urban heat island conditions.

NB-15: Develop and adopt a tree preservation ordinance.

NB-16: Update municipal code to eliminate minimum parking requirement for new developments.

NB-17: Use highly reflective materials for new or replacement roofs on City facilities.

NB-18: Develop guidance for green roof installations in Oklahoma City.

NB-19: Develop a cooling plan for the Central Business District.

Photo by the Office of James Burnett

ABOVE: TREE-LINED STREETS

Expanding the urban canopy can not only provide temporary relief for pedestrians but help in maintaining a cooler ambient air temperature and absorb vehicular emissions as a sort of buffer between traffic and pedestrians.

INITIATIVE 5

SUPPORT SMALL-SCALE FOOD PRODUCTION ON VACANT PUBLIC LAND OR UNDERUTILIZED PARK SPACE

Develop a pilot leasing program for urban garden plots on public land. Several successful program examples exist in other cities that allow leasing of underutilized public space for the purpose of gardening. Program partner commitments, maintenance agreements, and routine renewal reviews can ensure the land is used for productive, community-building purposes.

POLICY

NB-20: Develop a pilot leasing program for urban garden plots on public land.

UPPER RIGHT: Swiss chard grows in Guilford Gardens urban farm in NW Oklahoma City. The gardens are an example of community-supported agriculture that connects producers directly with consumers.

RIGHT: Farmer's markets and community gardens represent a revived appetite for locally-grown food and fresh produce but also reflect gaps in Oklahoma City's dearth of grocery stores and supermarkets offering fresh fruits and vegetables.

Photo by Nate Billings, the Oklahoman, 2016

Photo by Paul Hellstern, the Oklahoman, 2013