EXTREME WEATHER MITIGATION IN THE LAS CRUCES INFILL DISTRICT THROUGH GREEN STORMWATER INFRASTRUCTURE

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1. EXECUTIVE SUMMARY

Although Southwest communities have long experienced swings in temperatures and precipitation levels, historic patterns and general averages may no longer be a good indicator of the new normal of extreme weather events. Thanks to the generous support of the National Oceanic and Atmospheric Administration (NOAA), the City of Las Cruces and other local stakeholders worked with a project team of Southwest climatologists to examine the parameters of historic and projected weather patterns that have and could cause problems for the region.

One of the issues of concern addressed the health and safety of many vulnerable residents living in the urban center of Las Cruces known as the Infill District, (bounded by Interstate 25, Spruce Street, Main Street and University Avenue.) According to 2014 Census data, over 25 percent of the families in this area live below poverty; 33 percent of individuals over 65 live alone; and almost 20 percent are without health insurance. Much of this area is characterized by substandard housing, bare landscapes, and broad expanses of asphalt and concrete that contribute to an urban heath island (UHI) effect. Due to the combined impact of the UHI and predicted rising temperatures, these residents may not have the needed resources to respond to changing conditions, putting them at risk for heat stroke, exacerbated chronic conditions, and worse. Exposure to excessive natural heat, heat stroke, sun stroke, or all is the number one cause of weather-related deaths nationally. (Berko J, 2014)

Increased shade canopy, harvested stormwater, walkable streets, and green spaces can all mitigate UHI and buffer residents from rising temperatures. An “upstream” solution of this nature safeguards health and improves the community’s resiliency before serious problems occur. This report offers several capital improvement and policy strategies to use green infrastructure to augment the urban tree canopy along streets, in parking lots, parks, and ponding areas in the Infill District.

A $1.8 million investment in trees supported by green infrastructure will double the Infill District’s shade canopy while also conserving water, improving air quality, saving energy, reducing street maintenance costs, avoiding gray infrastructure costs, and increasing property value. This strategy also supports best practices described in the City’s new Municipal Stormwater Permit (MS4). To become a resilient city, it is incumbent to find upstream, cost effective, and mutually beneficial solutions. The strategies presented in this report reflect these criteria.

2. PREPARING FOR EXTREME WEATHER EVENTS IN THE LAS CRUCES INFILL DISTRICT

Predicted Weather Patterns for Las Cruces

As a southwestern desert city, Las Cruces is no stranger to extreme heat or drought conditions. Last season's extreme heat events over 100°F and 105°F are projected to become more frequent and last longer. Precipitation patterns will remain highly variable with more pronounced drought and heavy monsoons. According to the National Oceanic and Atmospheric Administration (NOAA) funded climate projection models developed for Las Cruces, the City has learned:

- There will be many more days per year with maximum temperature above 95°F, 100°F and 105°F and nights above 80°F (currently virtually non-existent);
- There will be many more hours per year when air conditioning is required and evaporative coolers will become less effective;
- Average summer precipitation, while continuing to be highly variable from year to year, shows no long-term trend and continued risk of very dry years similar to historical period;
- There will be a slight increase in the number of days per year with more than 2.5 inches of rain in 24 hours.

Conditions in the Infill Area

When one considers current socio-economic and environmental conditions in Las Cruces, the above projections are likely to have a severe impact on low and moderate income neighborhood areas. As shown in illustration 1 below, areas with concentrations of 40% or more households in poverty tend to be in older, central neighborhoods near downtown, and near the university campus. The City's Report to Housing and Urban Development (HUD), the Las Cruces Consolidated Plan 2016-2020 describes the housing stock conditions in this area:

> *A substantial portion of the single family and rental homes in Las Cruces are over 30 years old. They often need basic health and safety improvements to keep the older housing stock viable. Many homes need expensive system replacement such as new roofs, mechanical systems, plumbing, and electrical systems. Additionally, many homes lack energy efficiency improvements such as insulation, energy star heating and water heating systems, thermal windows, and weather stripping that will lower operating costs and make the homes more affordable to residents with limited income.* (City of Las Cruces, 2016, p. 119)

The City's limited shade canopy, (4.5%), does not help to buffer extreme heat events in these neighborhoods either. The central neighborhoods near downtown are made up of asphalt roads, narrow sidewalks, and cinderblock constructed homes with minimal landscaping.

The Las Cruces Urban Heat Island Effect shown in Illustration 2 below - where urban structures absorb heat and increase the air temperature in the area - also exacerbates these extreme heat events. With no increase in projected precipitation as well as an increase in large deluges occurring in a short period, this area can anticipate little respite from the heat.

The Extreme Weather Event Meetings and localized climate projections that were developed as part of the project funded by the National Oceanic and Atmospheric Administration (NOAA), has not only increased awareness of these projected changes, but brought attention to important steps the City of Las Cruces needs to make to increase its climate resiliency. This Study provides recommended strategies to address extreme heat events exacerbated by an Urban Heat Island Effect in the Infill Area of Las Cruces.

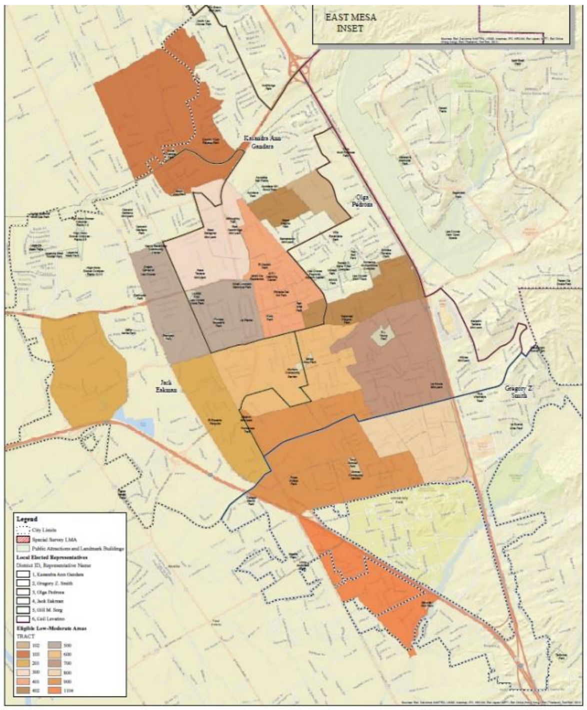


Illustration 1: Low and Moderate Income Neighborhoods in Las Cruces

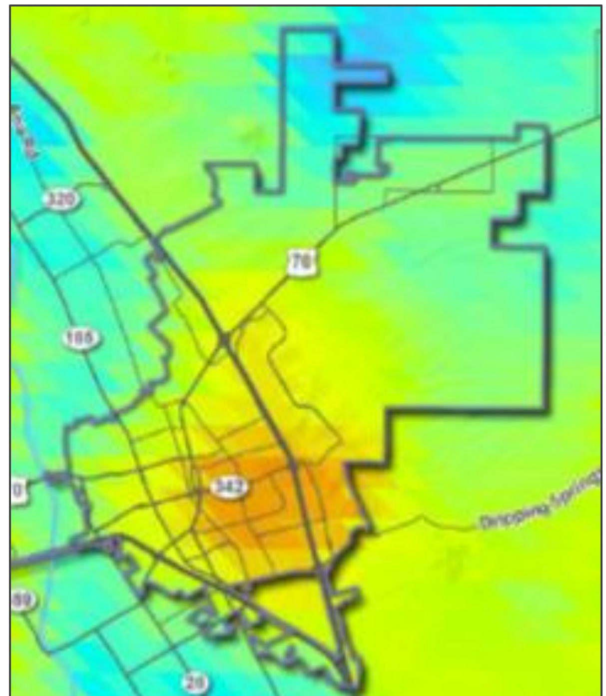


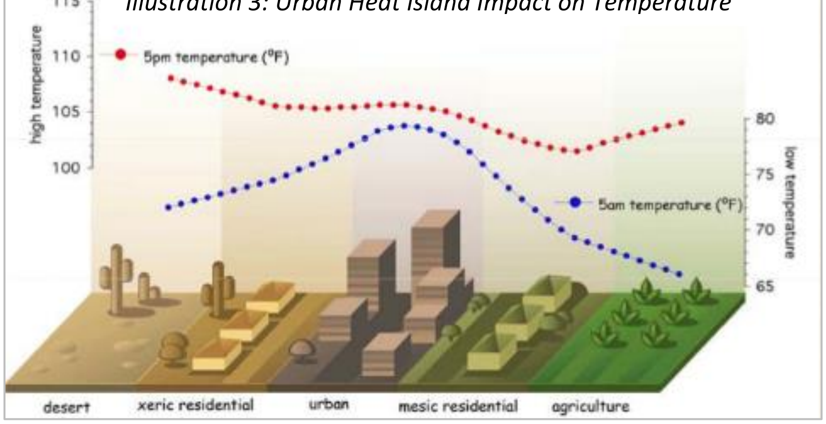
Illustration 2: Urban Heat Island Effect in Las Cruces

3. EXTREME HEAT AND URBAN HEAT ISLAND CHALLENGES IN INFILL DISTRICT

According to the EPA, "Urban Heat Islands" (UHI) occur when cities replace natural land cover with dense concentrations of pavement, buildings, and other surfaces that absorb and retain heat. This effect increases energy costs (e.g., for air conditioning), air pollution levels, and heat-related illness and mortality. (USEPA, 2016). Illustration 3 shows the UHI impact of dense environments relative to other landscape types.

Extreme heat and UHI disproportionally affect populations that have the least capability to adapt to increasing urban temperatures. Low income and elderly persons often cannot bear the added cost of more air conditioning days. Moving or relocating is often not an option. Strategies such as upgrading house insulation or other home improvements can be out of reach for those with limited or fixed income. (LTER, 2016) As seen in Illustration 1 and 2, the greatest current Urban Heat Island impacts occur primarily over a low- and moderate- income area in Las Cruces. (This area is roughly bounded by Interstate 25, Spruce Street, Main Street and University Avenue.) As a result, this report is targeted to characterize the most cost effective opportunities for UHI mitigation exacerbated by extreme heat events within the low-income area.

Illustration 3: Urban Heat Island Impact on Temperature



4. GREEN STORMWATER INFRASTRUCTURE BENEFITS FOR UHI AND EXTREME HEAT

Green Stormwater Infrastructure (GSI) provides multiple benefits to communities by harvesting stormwater in landscapes with the aim of reducing or eliminating potable irrigation needs for plants, including trees. By reducing and removing stormwater from streets while also growing native vegetation - without potable water- benefits accrue and can be quantified based on available research and tools. (Sikdar, 2015; Shipek, 2015; Maricopa, 2016; Tucson, 2015) (See section 6 for a summary of financial results from these tools.)

In the arid southwest, the most cost effective method to reduce urban heat island and extreme heat is to shade and prevent the sun's energy from being absorbed by dark surfaces such as buildings, roofs and roads with strategic planting of native trees. Other strategies such as green roofs, cool roofs, and alternative pavements are effective at reducing surface temperatures, but come at a higher cost than shade trees. Alternative pavement materials range in costs from $5-12 /square foot installed; green roofs. $10-220/square foot installed (Maricopa, 2016); while a tree canopy installed can cost $2-4 /square foot of canopy. (USEPA, 2016) GSI provides an optimal strategy for urban heat island reductions by utilizing stormwater that is typically treated as a waste material and turning it into a key resource for a robust urban tree canopy. Although a tree canopy is not immediate with tree plantings, native shade trees irrigated by GSI can provide rapid and robust canopy growth within 2-3 years (Pavao-Zuckerman, 2013).

Trees and vegetation lower surface and air temperatures by providing shade and through evapotranspiration. Shaded surfaces, for example, may be 20–45°F, (11–25°C), cooler than the peak temperatures of unshaded materials. (Akbari, 1997) Evapotranspiration cools the local environment through the daytime photosynthesis process as energy is consumed when the sun's energy converts liquid water in tree leaves to a vapor. (Ennos, 2016) Evapotranspiration, alone or in combination with shading, can help reduce peak summer temperatures by 2–9°F (1–5°C). (Huang, 1990; Kurn, 1994)

GSI BENEFITS

- Urban heat island effect reductions
- Water conservation
- Energy savings
- Reduced street maintenance from shaded pavement
- Stormwater runoff reduction
- Air quality improvement
- Property value increases
- Reduced grey infrastructure capacity needed
- Social value of water conservation
- Greenhouse gas emissions reductions
- Flood risk reduction
- Energy for water pumping
- Stormwater pollution reduction

5. GREEN STORMWATER INFRASTRUCTURE OPPORTUNITIES IN LAS CRUCES

Consultant, Watershed Management Group (WMG), used a standardized analysis to broadly assess a complete range of GSI project locations. A computer map assessment informed an initial survey of potential project locations. This was followed by an onsite visit and survey to verify computer observations. Below is a summary of the methodology and criteria utilized in this report.

Summary of Methodology

GSI opportunities can be identified and prioritized by a variety of criteria depending on regional priorities and challenges as well as available data. The intent of this project is to identify a broad range of opportunities. Future work can include prioritization of specific project ideas and locations. (No opportunities on private residential property were considered in this report due to the unknown potential for implementation rates, challenges of infrastructure maintenance to ensure quantifiable performance due to lack of access to private property, as well as narrow (< 5 ft.) residential rights-of-ways.) All criteria in bold were utilized to identify opportunities for this project.

- **Topography** – Does water flow to potential GSI inlets?
- **Utility locations** – Can minimum required distances (based on local ordinances between GSI and overhead and underground utilities) be maintained?
- **Available area** – Is the potential area at least 6 feet wide without any utility, pedestrian or other conflicts? (most relevant in rights-of-way)
- **Planned construction** – Is new construction being planned? For example, CLC Pavement Management System. See National Association of City Transportation Official's (NACTO) Urban Street Design Guide and Complete Streets with GSI (Smart Growth America, 2016) for additional street GSI references
- Drainage complaints & flood risk – Can GSI address local flooding challenges?
- Community resources – Can GSI enhance shade for community centers, parks, churches as well as other important community gathering spaces?
- Pedestrian and bike corridors – Can GSI be utilized to improve the comfort of alternative transportation infrastructure?

Onsite survey locations to assess potential GSI

The onsite survey included approximately 25 street miles. The analysis focused on priorities of higher potential for GSI based on a computer assessment with Google Maps, Google Street View and Google Earth. The 75 points recorded below exemplify the range of GSI project types (parking lots, in-street, detention/retention basins, or parks) and locations of potential GSI sites based on the above criteria in bold. This is not an exhaustive survey. The areas where gaps exist in the markings on the map below are a result of residential and commercial areas that do not have unique features such as the many overwide residential streets. (An electronic copy titled Las Cruces.kmz has also been provided with all electronic data captured in this project.) The opportunity areas identified in this file were drawn according to the estimated potential area and do not necessarily reflect the exact location of GSI features. Points were marked to highlight unique GSI opportunities such as vacant lots, overwide intersections/streets and park GSI opportunities.

GSI opportunities in the Las Cruces Infill District fall in the following general areas:

a. commercial parking lot retrofits
b. Neighborhood street cooling
c. Detention/retention pond retrofits
d. park enhancements

A. COMMERCIAL PARKING LOT RETROFITS

Current conditions

There are approximately 90 parking lots as show in the picture below representing almost 1.5 square miles or 30% of the project area. These parking lots produce over 250 million gallons of stormwater per year. This is enough to irrigate over 50,000 mature native shade trees which would shade 100% of the parking areas. Significant opportunity exists for new design standards for parking lot retrofits as well as new parking lot construction or reconstruction. Whether at a church or a “big box” store, parking lots are a major element of many neighborhoods. Their presence, though often necessary, has several consequences for the local environment and neighborhood character. Runoff accumulates quickly, and in many neighborhoods, this stormwater is sent out into the street or directly into arroyos and washes. To utilize this wasted resource, many municipalities now require parking lots to be outfitted with detention/retention basins that capture stormwater runoff. In place of a conventional detention/retention basin, redeveloped or new parking lots can be graded to direct runoff to landscape areas before entering a storm drain with no additional costs.

Parking lots in the Infill District produce over 250 million gallons of stormwater per year, enough water to irrigate over 50,000 mature native shade trees which would shade 100% of the parking areas.

GSI practices and benefits

Currently, storm water is a liability as it picks up sediment from adjacent landscapes and hydrocarbons and brake dust from automobiles. When allowing the water to collect in larger volumes and increase in velocity, the erosive forces and the concentration of pollutants in the detention/retention basins increase. Rock lined retention basins are not designed for treating the pollutants that accumulate in soil and water over time, and worse are carried downstream polluting other bodies of water. (Watershed Management Group, Green Infrastructure Manual for Southwest Communities, 2017). By utilizing distributed GSI throughout a parking lot to harvest stormwater close to where it falls, pollutants can be treated by soil microbes and native plant root systems (USEPA, Office of Water, 1999) while also conserving water in parking lot landscapes and reducing extreme heat impacts from the broad expanse of parking lot asphalt. When retention/detention capacity is spread throughout existing landscape areas, additional developable land can be created by eliminating the space required by a large basin that often required a fence and barbed wire to prevent the public from entering a dangerously deep area while also beautifying the property lots. This becomes an appreciable amenity for the area.

McPherson and Muchnick (2005) determined that the number of maintenance seal coats required for asphalt to be maintained in an arid environment significantly decreases when the asphalt is shaded. Improving pavement life is also a significant benefit of GSI. For every acre of parking lot approximately, 2,200 square feet of GSI supporting 44 trees would be required to shade the entire parking lot. This would generate $4,400 per acre in total annual benefits. For an average Walmart parking lot of about 8.5 acres in size, approximately $2,500 in annual benefits would be created if the parking lot were rebuilt with GSI retrofits from reduced asphalt maintenance alone. The Walmart parking lot would result in approximately $38,000 in total annual benefits based on the complete analysis of financial costs and benefits in Section 6.

For every acre of parking lot approximately, 2,200 square feet of GSI supporting 44 trees would be required to shade the entire parking lot. This would generate $4,400 per acre in total annual benefits.

Design standards

When designing GSI for parking lots follow these best practices:

- To protect the asphalt surface, reinforce cut asphalt edges with flush concrete header, 6” wide by 12” – 18” deep.
- In areas where there is a risk of motorists driving into GSI areas, use concrete curb stops at the pavement margin or landscape boulders within the basin to prevent vehicle entry, or use a raised curb with curb cuts to allow stormwater flow while deterring vehicles.
- Plan for where overflow will exit bioretention features and, where possible, route to the next downstream basin.

GSI Parking Lot Designs

This parking lot at the Tucson Association of Realtors was designed to mitigate flooding with GSI while also meeting the commercial water harvesting ordinance of providing 50% of the landscape irrigation needs with rainwater or stormwater.

The photos above show a parking lot median with flush curbs created in over-long parking spaces to harvest stormwater sheet flowing from left to right in the picture before flowing off into a lake.

Two different design options with flush curbs (left) or with raised curbs and a specific stormwater inflow point (right).

B. NEIGHBORHOOD STREET COOLING

Incorporating shade trees using GSI within the City's scheduled Capital Improvement Projects for the Infill District will result in asphalt maintenance savings of $100,000 annually.

Current conditions

Many neighborhood streets in Las Cruces are overwide (greater than 22' wide for two lanes of traffic or 32' for two lanes plus parking) and present a significant opportunity to utilize GSI to cool and beautify neighborhoods. Based on McPherson (2005), for every mile of 40' wide street shaded with GSI, over $25,000 of annual financial benefits are created from reduced asphalt maintenance alone. In the Infill District there are approximately 5 miles of streets to be rebuilt through the City of Las Cruces Capital Improvement Program in the next five years. Assuming streets are 32' wide this would result in asphalt maintenance savings of $100,000 annually. (See Section 6 for a complete analysis of the benefits of GSI.)

GSI practices and benefits

There are two broad categories of street features that can be implemented in neighborhood streets: street side features and in-street features.

Street side features are basins with curb inlets such as curb cuts and are often used to retrofit existing rights-of ways. These features are appropriate on crowned roadways where the lowest point of the roadway is by the curb. This allows water to flow along the gutter and be harvested when the curb is cut and the adjacent landscape is below the street grade. Curb inlets are useful for retrofitting existing neighborhoods with GSI practices without major reconstruction. Cutting or coring curbs is significantly cheaper than working to collect stormwater via in-street practices. Since curb cut openings are perpendicular to the flow of stormwater on the street, they will usually collect only a portion of the water flowing along the gutter. If attenuating stormwater flows along the street is the goal, placing multiple curb cuts at intervals along the street achieves this.

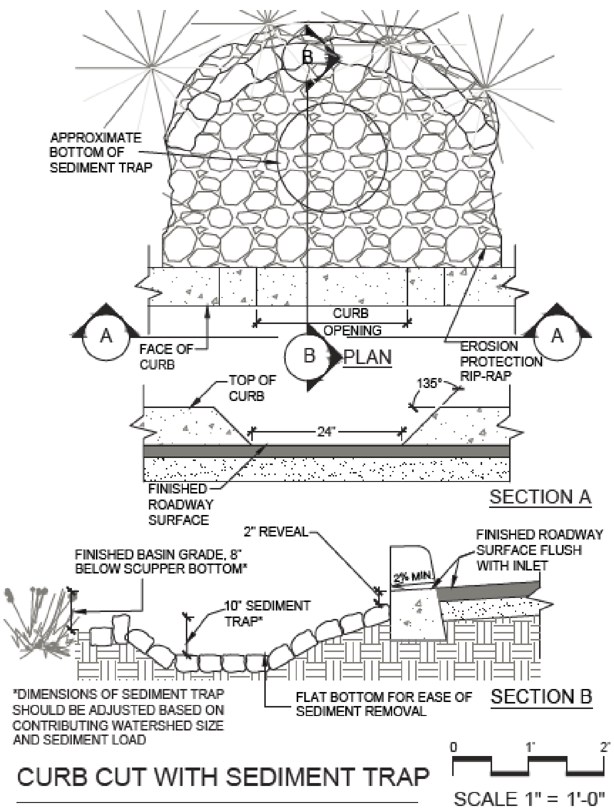
In-street features within neighborhoods provide many benefits for parked vehicles, residents and pedestrians by directly shading street surfaces as well as pedestrian walk ways. In-street feature advantages include: 1) significant traffic calming by reducing roadway widths that result in lower vehicle speeds (Retting, 2003); 2) possible use in areas where rights-of-ways are narrow or have utility conflicts; 3) increasing storm water harvesting beyond street side features; and, 4) dramatically improving streetscape and neighborhood aesthetics. In-street features are more expensive to construct due to the need to remove and relay asphalt as well as pouring new concrete curbing.

Standards

Typically, in Tucson, curb cuts are 18" to 24" wide, with 45 degree sloped sides. Variations based on curb type or in other communities have also been successful (see photos below.) The bottom of a curb cut should slope away from the street and slightly toward basin area. A rip-rap apron (sediment trap) should be built where the water flow crosses the cut curb into the ROW area. The apron will prevent soil erosion and undercutting of the road surface. Rock sized 4" to 8" can be laid in a single well-fitted course around the entrance. The top of the rock surface should be laid 1" to 2" below the level of the bottom of the curb cut to ensure positive water flow into the basin.

A standard detail for a curb cut with a sediment trap is found on the following page. Sediment traps provide a critical function by preventing sediment from clogging infiltration basins, thereby ensuring long-term performance of GSI.

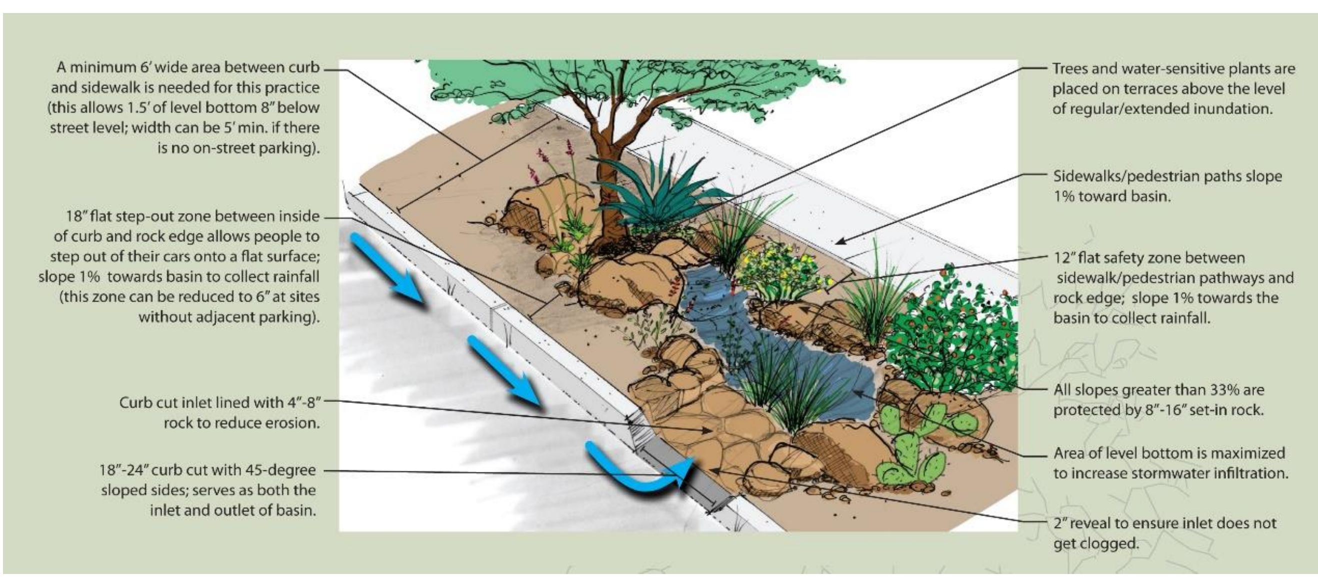
BEST PRACTICES FOR STREET FEATURES




Curb cuts can still work on wedge curbs


An angled curb cut enhances stormwater capture.

Photo by Stream Dynamics, Silver City, NM



Primera Iglesia, Phoenix, AZ
2011 (left) and 2014 (below left)

Even in the extreme climate of Phoenix, street side GSI can meet all irrigation needs for a native landscape after establishment.

The image below shows an overwide (>32') street road diet on North 5th Ave in Tucson, Arizona and standard detail for GSI features.

C. DETENTION AND RETENTION POND RETROFITS

Current conditions

A rock lined basin with no sediment trap in Tucson holds water after a week after a rain event limiting the storage capacity of the basin and increasing the risk of mosquitoes.

Typical retention and detention basins in Las Cruces tend to serve a single purpose to reduce peak downstream flows which have been increased due to impervious development. Often basins in Las Cruces have rock lined bottoms which make them difficult to maintain and often create ponding as silt builds up decreasing infiltration capacity. In many cases soil is compacted during the basin construction process and would benefit from being ripped/tilled. Almost 40 acres of detention basins exist in the infill district. Stormwater in these basins could support over 1,500 trees, providing over 10% of the total trees needed to increase the infill district tree canopy by 5%.

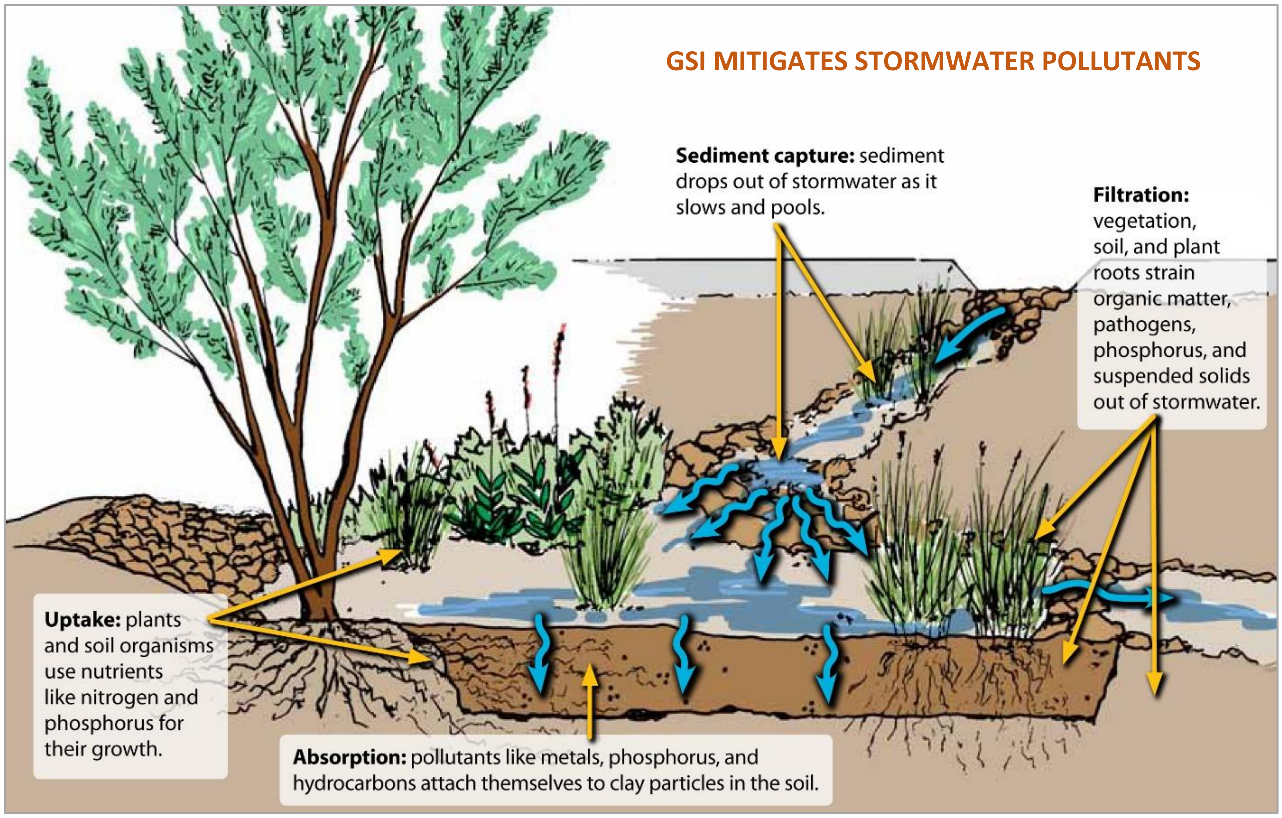
GSI practices and benefits

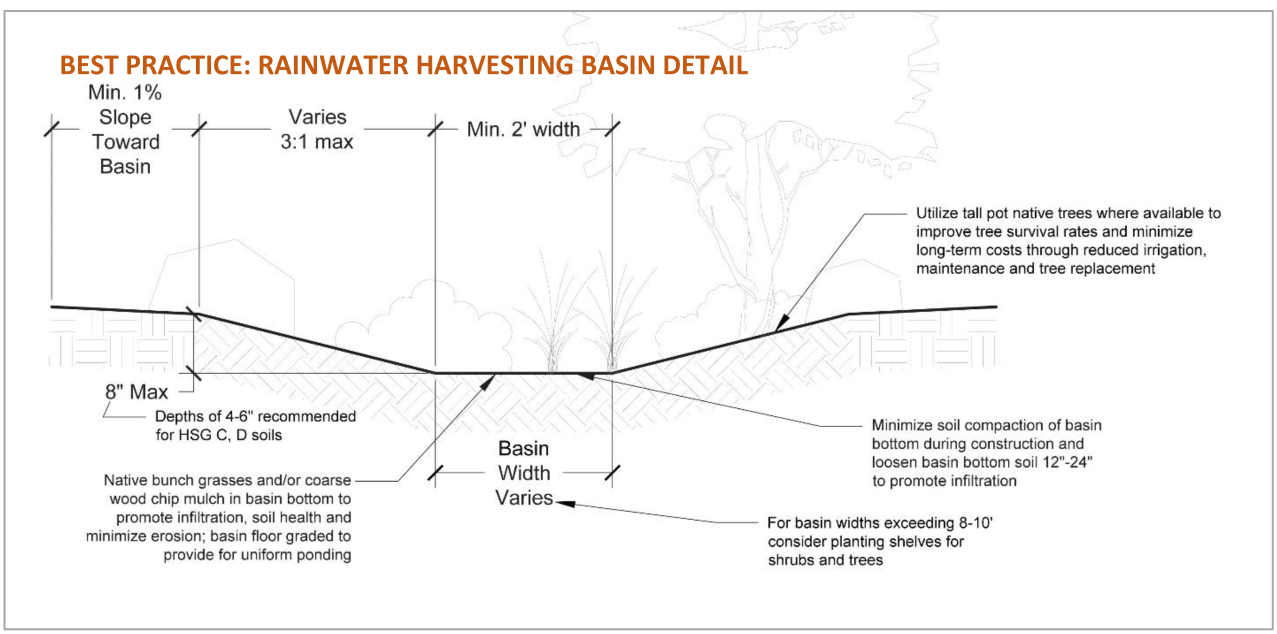
Existing basins can be modified to include native shade trees to mitigate heat and harvest storm water. Native bunch grasses and sediment traps increase infiltration rates as well as periodic maintenance. (Watershed Management Group, Rain Garden Field Guide, 2014). Stormwater pollution reductions can be maximized with the presence of organic matter like mulch and native vegetation. Mulch provides an energy source for microbes, fungi and bacteria to breakdown pollutants as their food source and can turn hydrocarbons and other pollutants into less harmful by products (Pavao-Zuckerman, 2013; Watershed Management Group, Green Infrastructure Manual for Southwest Communities, 2017). Appropriately designed GSI features show reductions of 54-92% of the following water quality parameters: suspended solids, nitrogen, phosphorus, heavy metals (copper, lead, zinc and cadmium), hydrocarbons, and pathogenic bacteria (Davis, 2009).

Appropriately designed GSI features show reductions of 54-92% of the following water quality parameters: suspended solids, nitrogen, phosphorus, heavy metals (copper, lead, zinc and cadmium), hydrocarbons, and pathogenic bacteria (Davis, 2009).

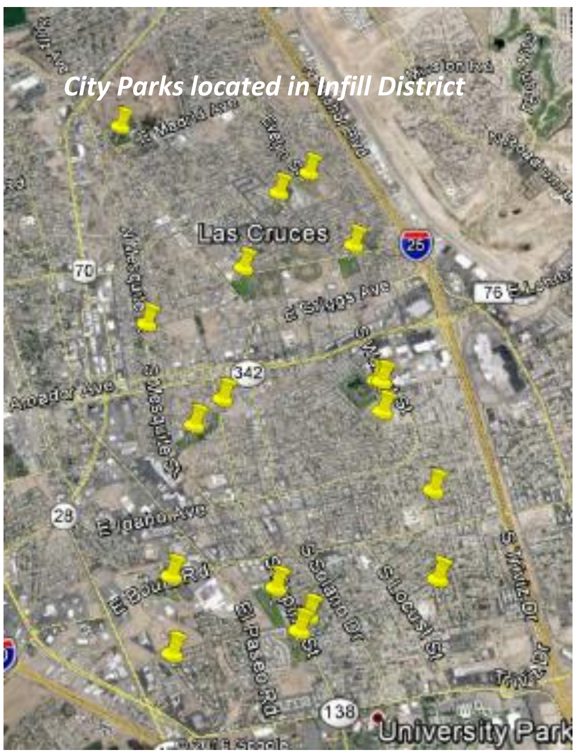
Design Standards

In deep basins, planting shelves and natural stormwater conveyance swales could be constructed to maximize stormwater pollutants by directing stormwater to the root zones of trees and vegetation located high on the basin edges above the ponding area to provide native shade tree canopy growth for UHI reductions (Stormwater PA, 2016). The practices from Stormwater PA needs to be adapted to arid climates and incorporate design criteria to ensure maximum UHI benefits such as locating shade trees at basin edges to ensure shading of adjacent hardscapes such as streets and parking lots.


GSI MITIGATES STORMWATER POLLUTANTS
Sediment capture: sediment drops out of stormwater as it slows and pools.
Filtration: vegetation, soil, and plant roots strain organic matter, pathogens, phosphorus, and suspended solids out of stormwater.
Uptake: plants and soil organisms use nutrients like nitrogen and phosphorus for their growth.
Absorption: pollutants like metals, phosphorus, and hydrocarbons attach themselves to clay particles in the soil.


BEST PRACTICE: RAINWATER HARVESTING BASIN DETAIL
Min. 1% Slope Toward Basin
Varies 3:1 max
Min. 2' width
Utilize tall pot native trees where available to improve tree survival rates and minimize long-term costs through reduced irrigation, maintenance and tree replacement
8" Max
Depths of 4-6" recommended for HSG C, D soils
Minimize soil compaction of basin bottom during construction and loosen basin bottom soil 12"-24" to promote infiltration
Basin Width Varies
Native bunch grasses and/or coarse wood chip mulch in basin bottom to promote infiltration, soil health and minimize erosion; basin floor graded to provide for uniform ponding
For basin widths exceeding 8-10' consider planting shelves for shrubs and trees

For every acre of GSI created in parks, over $85,000 of *annual* economic benefits are created while only costing $110,000 in initial capital costs. The City owns 17 parks within the 5-square mile project area totaling almost 14 acres that are suitable for GSI. A $1.5 million investment would provide almost $12 million in economic benefits over 10 years.



City Parks located in Infill District

The GSI at Maag Field at the Hadley Avenue Recreation Area harvests stormwater from the adjacent parking lot and serves as a great example of the potential for larger scale GSI with available park space.

D. PARK ENHANCEMENTS

Current conditions

There are 17 parks marked in the map with areas suitable for GSI totaling approximately 600,000 square feet or 14 acres. Park open spaces provide tremendous opportunities for stormwater pollutant and peak flow reductions as well as significant irrigation benefits through the use of GSI.

Practices and benefits

When topography allows, stormwater can be harvested from adjacent hardscapes such as buildings, roads and parking lots. For every acre of GSI created in parks, over $85,000 of annual economic benefits are created while only costing $110,000 in initial capital costs. Based on the experiences at Maag Field. parks have the highest potential for cost-effective water savings. Park GSI cost effectiveness is due to the relatively high water use for turf field irrigation, available area for GSI and no need for asphalt/concrete removal and replacement. With 14 acres of City Parks, a $1.5 million investment would provide almost $12 million in economic benefits over 10 years.

When turf is replaced with GSI, the new landscape can thrive on stormwater alone after establishment (see photos of Primera Iglesia in Phoenix on page 12) while also eliminating the need to irrigate the turf. Native shade trees can be located to maximize the benefit to park users as well as for shading adjacent hardscape surfaces to reduce the UHI. Long-term maintenance for park staff can be reduced over turf landscapes by providing root barriers from adjacent turf, ensuring full coverage of GSI soil by new plantings or native seed and providing sufficient initial physical removal of invasive and unwanted plant materials.

Maag Field GSI harvesting parking lot stormwater.

6. SUMMARY OF GREEN STORMWATER INFRASTRUCTURE BENEFITS AND COSTS

Potential scale of GSI

Sample area used to determine potential for GSI bounded by El Paseo, Espina, Missouri, and Idaho.

Many locations for GSI were identified throughout the project area. While a complete catalogue of all the project opportunities is not possible under the scope of this project, a sample area highlighted in the map below was analyzed for the potential GSI coverage. This area was selected for its approximation of representative property types (residential, commercial, and vacant lots). All potential GSI sites were identified within this sample area based on topography and available area. This resulted in approximately 5 acres (8%) of GSI coverage. Based on this sample analysis, the entire project area of 5.18 square miles (3,313 acres) could benefit from approximately 260 acres of GSI. The potential 260 acres of GSI would have a stormwater capacity of 130 acre-feet based on an average feature depth of 6 inches. Some areas would be able to utilize depths up to 12 inches if the soil conditions allow for sufficient percolation within 24 hours. (Percolation in less than 24 hours is critical to ensure no mosquito risk from GSI.)

Cost/benefit analysis

The cost benefit analysis values accounted for in this study are divided into two categories: direct, (designated as green in the table below), and indirect, (blue), economic values. Direct economic values have a market value that benefits the property owner, community, or local government such as utility costs or maintenance reductions. Indirect economic values are not currently reflected by local or regional markets but can be estimated through related costs to society. For example, extreme temperatures as a result of the urban heat island effect result in medical costs that are borne typically by elderly populations. By reducing the risk of stress through GSI, it is possible to reduce the occurrence of heat stress related costs.

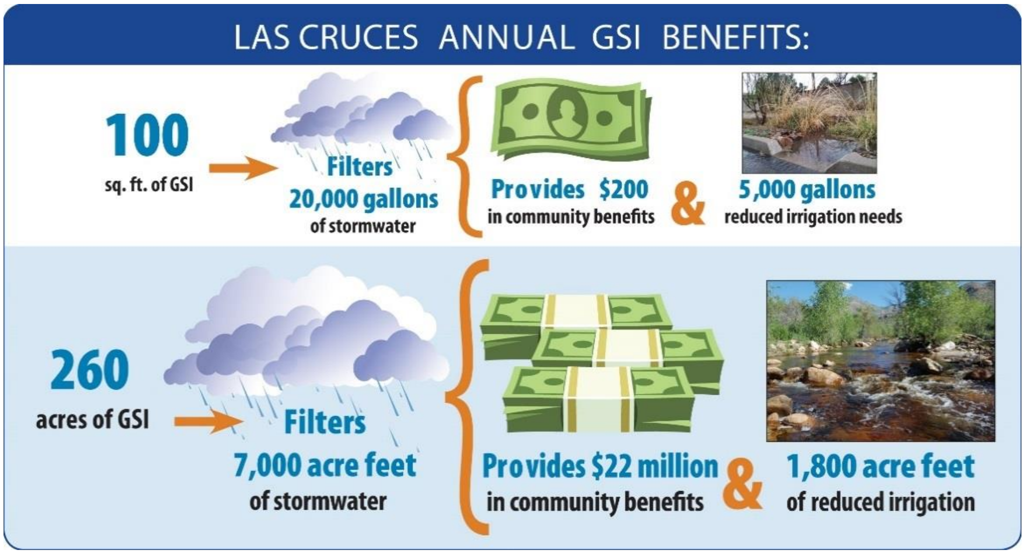
WMG's Cost Benefit Analysis utilized in Sierra Vista (Shipek, 2015) captures all the benefits presented at the beginning of section 2 and was modified for local conditions in Las Cruces. These modifications are based on rainfall, water prices, energy prices and property values. All other Sierra Vista data were assumed to be reasonable proxies for local conditions in Las Cruces. For a complete description of the benefits analyzed in this report, see the Appendix. Below is a tabular and graphical summary of annual benefits for a 100-square foot GSI feature, and a projected 20%, 50%, 100% capacity GSI project in the infill district.

The Infill District project area of 5.18 square miles (3,313 acres) could benefit from approximately 260 acres of GSI. The potential 260 acres of GSI would have a stormwater capacity of 130 acre-feet based on an average feature depth of 6 inches.

Las Cruces Infill District **ANNUAL GREEN INFRASTRUCTURE COST BENEFIT ANALYSIS**					
		per 100 sq. ft.	**25% GSI CAPACITY**	**50% GSI CAPACITY**	**100% GSI CAPACITY**
	units in acres		**65**	**130**	**260**
	units of 100 square feet	**1**	**28,314**	**56,628**	**113,256**
DIRECT BENEFITS ($/year)	water conservation	$ 15.34	$ 434,337	$ 868,658	$ 1,737,347
	air quality improvement	$ 15.80	$ 447,361	$ 894,707	$ 1,789,445
	energy savings	$ 10.01	$ 283,423	$ 566,836	$ 1,133,693
	street maintenance	$ 13.05	$ 369,498	$ 738,982	$ 1,477,991
	gray infrastructure avoided	$ 7.47	$ 211,506	$ 423,004	$ 846,022
	property value	$ 0.34	$ 9,627	$ 19,253	$ 38,507
	Subtotal ($/year)	**$62.01**	**$ 1,755,751**	**$ 3,511,440**	**$ 7,023,005**
INDIRECT BENEFITS ($/year)	social value of water conservation	$ 24.70	$ 699,356	$ 1,398,712	$ 2,797,423
	greenhouse gas emissions reductions`	$ 13.36	$ 378,275	$ 756,550	$ 1,513,100
	flood risk reductions	$ 0.58	$ 16,422	$ 32,844	$ 65,688
	energy cost of water	$ 0.79	$ 22,368	$ 44,736	$ 89,472
	stormwater pollution reduction	$ 0.70	$ 19,820	$ 39,640	$ 79,279
	traffic calming	$ 97.34	$ 2,756,085	$ 5,512,170	$ 11,024,339
	urban heat island	$ 0.37	$ 10,476	$ 20,952	$ 41,905
	Subtotal ($/year)	**$137.84**	**$ 3,902,802**	**$ 7,805,604**	**$ 15,611,207**
	Total ($/year) (direct and indirect)	**$200**	**$ 5,658,552**	**$ 11,317,044**	**22,634,212**
	stormwater harvested (in 1000 gallons per year)	**20**	**566,280**	**1,132,560**	**2,265,120**
	stormwater harvested In acre feet/year	**.06**	**1,738**	**3,475**	**6,951**
	Number of trees supported	**2**	**1,132,560**	**2,265,120**	**4,530,240**

GSI and stormwater

For every 100 square feet of GSI being fed by an urban watershed, it is estimated that approximately 20,000 gallons of stormwater flow through the GSI feature[i]. This can vary based on contributing watershed size and GSI inlet and flow capacity. The irrigation benefit is based on the plant demands for two large native shade tree and six other grasses and shrubs that are met through GSI.



Another relevant and potentially significant financial benefit not accounted for in the analysis is recharge potential. Recharging stormwater through GSI provides a cost-effective method to reduce pollutants in stormwater and enhance long-term groundwater supplies while also restoring natural hydrological patterns to urban environments.

GSI vs non-GSI cost comparison

The most cost effective method to realize the above benefits is to design GSI practices into new construction and redevelopment. The City of Las Cruces Pavement Management Analysis and resulting priority road projects included in the CIP budget are ideal candidates to incorporate GSI into beneficial city infrastructure and assets. Throughout the United States, GSI provides significant cost savings ($2,000 to $15,000/acre of new or redevelopment) over traditional stormwater management practices by providing higher water quality improvements, increased developable area as well as reduced or eliminated traditional stormwater infrastructure (EPA, 2016; ECONNorthwest, 2007). Landscape costs for GSI street projects in City of Tucson ranged from $70 to $250 per linear foot, while comparable traditional landscapes ranged from $40 to $200 per linear foot. It is important to note that variability in costs between GSI vs non-GSI landscapes were more due to specific design choices and length of project. Initial results show no significant increase in costs for GSI vs non-GSI projects (City of Tucson, 2015). By focusing on low-cost/no-cost functional design features such as uncompacted native soil with simple curb cuts and scuppers/grates for streets projects, GSI can be provided at similar costs to traditional landscape with the additional water quality and conservation benefits. Additional cost savings can be achieved by creatively designing GSI to reduce planned stormwater infrastructure costs as well as maintenance. Costs can be saved by reducing sediment and trash from entering storm sewer drains.

Throughout the United States, GSI provides significant cost savings ($2,000 to $15,000/acre of new or redevelopment) over traditional stormwater management practices by providing higher water quality improvements, increased developable area as well as reduced or eliminated traditional stormwater infrastructure (EPA, 2016; ECONNorthwest, 2007).

GSI per square foot	
In-street GSI	$1-10
City Parks GSI	$2.50
Parking lot GSI	$5-$10

Over the life of GSI, for every dollar invested, $2-7 will be returned to the community in direct and indirect benefits.

GSI construction costs

Based on WMG's construction experience, expected GSI retrofit costs would range from $1 -$10 per square foot of GSI depending on if asphalt removal and concrete pour as is necessary for in-street projects. Park GSI projects will likely fall in the range of $2.50/square foot based on recent experience at Maag Field and the potential to increase efficiency of design and construction on future projects. Parking lot GSI may not increase costs if incorporated as a part of new or redevelopment. If parking lot GSI is included as a part of a retrofit, based on WMG's experience, costs will likely be in the range of $5-$10/square foot.

Payback

When accounting for the above benefits and costs as well as routine maintenance infrastructure, GSI features have a positive return on investment typically after 6 (direct and indirect benefits) to 8 (only direct) years. Over the life of GSI, for every dollar invested, $2-7 will be returned to the community in direct and indirect benefits.

Shade Canopy Goals

The table below outlines different tree canopy goals for the project area of approximately 5 square miles. The number of trees are based on two native trees creating a canopy of 2,000 square feet total and costs are based on $5/per square foot for an average retrofit cost. If all canopy goals could be incorporated within street CIP funding for new construction, these costs could be greatly reduced if not, eliminated. The time for implementing goals was set at a 10-year period

Canopy Goal	Canopy Needed		Cost		Benefits	Trees		GSI Capacity	
Increase	square feet	acres	Total	$/yr*	$/yr**	Total	trees/yr	square feet	acres
1%	1,443,410	33	$360,852	$36,085	$144,341	1,443	144	72,170	2
2%	2,886,819	67	$721,705	$72,170	$288,682	2,887	289	144,341	3
5%	7,217,048	167	$1,804,262	$180,426	$721,705	7,217	722	360,852	8
10%	14,434,097	334	$3,608,524	$360,852	$1,443,410	14,434	1,443	721,705	17
15%	21,651,145	501	$5,412,786	$541,279	$2,165,115	21,651	2,165	1,082,557	25
20%	28,868,193	667	$7,217,048	$721,705	$2,886,819	28,868	2,887	1,443,410	33
25%	36,085,242	834	$9,021,310	$902,131	$3,608,524	36,085	3,609	1,804,262	42

**Annual costs spread over 10 years*
***Annual benefits if all GSI capacity installed*

A 5% increase (over the existing 4.5%) in canopy was selected as a goal based on the expected realities of funding and local design and construction capacity. Additional training and capacity building would be necessary to speed up design and construction while maintaining quality of GSI implementation.

7. OVERVIEW OF POTENTIAL POLICY OPTIONS

Policies and incentives are powerful tools to drive GSI in new construction and retrofit scenarios. A key component to any policy or incentive is providing resources for inspection, enforcement, follow up and maintenance to ensure GSI is constructed and maintained appropriately.

a. Parking lot tree canopy and water harvesting policy

A performance-based tree canopy policy is recommended. City of Tucson requires one tree for every four spaces. Parking lots have sufficient surface area to provide all needed irrigation for 100% canopy coverage from mature native shade trees with stormwater runoff from GSI given appropriate design and grading. Incentives could be offered if additional hardscapes such as streets, sidewalks and roofs are designed to direct stormwater to GSI before storm drains.

b. Residential rainwater harvesting rebates

Tucson and many other arid cities offer rebates for water harvesting. (City of Tucson, 2016) Tucson has recently expanded its rebate program to include funding street side GSI that results in UHI reductions, water conservation and flood mitigation benefits. (City of Tucson, 2016)

c. Commercial water harvesting policy

All commercial landscapes must meet 50% of landscape irrigation needs with rainwater harvesting GSI. (City of Tucson, 2008) Best practices have not been enforced and landscapes have become gravel covered pits that get sprayed with pesticides and herbicides and native trees are severely pruned. A performance based policy revision to include canopy goals is preferred. Additional outcomes regarding water quality can be specified to meet Las Cruces' MS4 permit requirements.

d. Green streets policy

For all new construction of streets in the city of Tucson, the Green Streets Policy (City of Tucson, 2013) requires that GSI meet 50% of irrigation needs and support a 25% tree canopy. See the active practice guidelines for more information on best practices (City of Tucson, 2013)

e. Parking alignment for optimal shade and water harvesting

Aligning parking spaces to be oriented East/West so that GSI tree plantings can be North/South will allow for maximum UHI reductions. Parking lots should be graded for distributed water harvesting. By spreading stormwater throughout GSI landscapes, irrigation benefits and flood potential reductions can be maximized.

f. Potential development code revisions

The following items are potential opportunities to revise development codes for new development to reduce future UHI impacts exacerbated by extreme heat events. This list is not exhaustive and specific recommendations cannot be made without a review of existing development codes in collaboration with Community Development.

- Neighborhood street narrowing
- Excessive pavement at intersections
- Cul-de-sac dimensions for landscaped median
- Detention pond retrofit for shade tree irrigation

g. Vacant properties

Vacant properties present a tremendous opportunity to convert derelict land into city assets with GSI providing stormwater management and flood mitigation benefits. GSI features can also be community assets by creating shaded community gardens, pocket parks and other community gathering spaces. Design considerations will be similar to park spaces.

8. CONCLUSION AND ACTION PLAN

GSI provides significant financial and environmental benefits over traditional stormwater management. In the face of climate change and increasing urban heat island impacts, GSI provides an ideal infrastructure solution to utilize wasted stormwater to benefit the community while reducing overall costs to provide infrastructure services relative to traditional stormwater management methods.

Based on the opportunities outlined in this report and the goal set forth to increase canopy by 5 percent in 10 years, it is recommended the city focus on the following key areas in order to maximize cost savings and benefits:

1. Incorporate GSI into all relevant CIP projects and processes supported by a Green Street Policy;
2. Position park open space adjacent to hardscape surfaces for GSI to maximize benefits to park users and UHI;
3. Implement policies a parking lot tree canopy and water harvesting policy, commercial water harvesting policy, and parking alignment for optimal shade and water harvesting to promote sound design of parking infrastructure to reduce property owners' maintenance and operations costs; and
4. Develop a policy to utilize vacant properties for GSI.

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10. APPENDIX: COST BENEFIT ANALYSIS TERMS

The greatest contribution to GSI value is from water conservation, energy and property values. CLC specific data were utilized to customize the cost benefit analysis. Data for less significant benefits utilized data from the City of Sierra Vista given its similar climate, soil conditions and elevation.

Below is a detailed summary of economic values calculated for GSI. For additional details on the research that supports these costs see the footnotes, i-Tree references, and the Business Case Evaluator (BCE) report 'Evaluation of GI/LID Benefits in the Pima County Environment'.[ii] Regression analyses, cost data based on WMG's experience and outputs from these tools were summarized in a Microsoft Excel spreadsheet in order to develop a method to quickly calculate watershed scale results.

Direct Benefits

Water Conservation – Water demand during establishment for rain gardens was based on low water use plants[iii] for two native trees, 4 grasses, 2 groundcover plants and 2 shrubs for every 100 square feet of basin area. It is assumed that GSI has similar irrigation efficiencies as flood irrigation. Flood irrigation efficiencies range from 40-85%[iv]. A conservative value of 50% is used here. Irrigation demand is reduced by 50% for commercial properties as used by City of Tucson Commercial development requirements. It is assumed that irrigation to GSI is discontinued after the first 3 years of plant establishment.

Air Quality Improvement – The BCE tool was used to define a relationship between number of trees planted and benefit value. Air quality benefits are calculated in the BCE as the sum of reduced emissions of air pollutants from power-generating plants, and the value of pollutant uptake from trees.

Energy Savings – The i-Tree Streets tool was used to define a relationship between number of trees planted and benefit value. Energy savings are based on reduction in air conditioning and heating bills as a result of tree shade. This value is calculated using the method described by McPherson et al.,[v] which uses a typical single family residence to model energy simulations.

Reduced Street Maintenance – Shade created by trees installed with GSI extends the life of asphalt pavement, reducing the maintenance required. As shown by McPherson & Muchnick,[vi] significant financial savings can occur from pavement shading.

Property Values – Property value increases occur as a result of local environmental attributes. Studies show that each large front yard tree is associated with a 0.88% increase in property value.[vii] The BCE[viii] uses local property values and applies research values to estimate the increase in property value due to GSI projects. The BCE tool was used to define a relationship between water harvesting basin dimensions, number of trees planted and benefit value.

Avoided Grey Infrastructure – Potential savings of large scale flood mitigation infrastructure if GSI retention is taken into account in sizing detention basins, storm drains or culverts. Values used in the CBA are based on the cost estimates of proposed grey alternatives for the Airport Wash area and conservative estimates of savings. Additionally included in this benefit is the amount of water intercepted by trees planted, estimated using the i-Tree Streets tool. McPherson et al. used Glendale, Arizona's cost for retention/detention basins to determine the value of water collected and stored by trees.

Indirect Benefits

Social Value of Water Conservation - The indirect cost of water is determined by the cost of water extraction and purification from alternative water sources. The cost of water from alternative sources was found in "Augmentation Alternatives for the Sierra Vista Sub-watershed, Arizona."[ix] The alternatives presented in this report were summarized in another USGS report[x] and implementation of the cheapest alternative was assumed.

Greenhouse Gas Emissions Reduction – The carbon reduction value from the BCE was calculated by subtracting the carbon emissions emitted during construction from the total benefits of decreased energy use in lifetime maintenance for the project and the carbon sequestration as a result of tree plantings. The average value for carbon emissions utilized based on BCE research is $50/metric ton.

Flood Risk Reduction – The flood risk reduction value is based on water that is retained by water harvesting basins. The BCE [xi] models rainfall in Tucson (nearest city included in BCE tool to Sierra Vista) over the next 100 years to determine a rainfall model that is used to determine flood damages that are mitigated by the reduced runoff volume associated with active and passive rainwater harvesting.

Groundwater Pumping – The average energy used to source and treat one gallon of groundwater in Arizona is 0.0013 kWh.[xii] The cost for 1 kWh of energy is $0.106.[xiii] This number was used to determine the value of water harvesting features that require no additional energy input.

Stormwater Pollution Reduction – Water harvesting basins and tree plantings provide the service of removing pollutants and heavy metals from runoff and treating them through natural filtration. There are regions in the southwest that have a stormwater utility fee that provides incentives for GSI implementation to meet stormwater management needs. Property owners who implement GSI have reduced utility fees as a means to incentivize GSI. These fee reductions for GSI represent the best local approximation of the economic benefits of stormwater pollution reduction from GSI. Costs are based on Oro Valley's fee structure of $2.90 per equivalent residential unit. [xiv]

Urban Heat Island – The urban heat island effect occurs in urban areas where temperature is often higher than that of surrounding rural areas. This is due to the density of impervious surfaces and lack of trees in urban areas, which allows heat to be stored and slowly released, keeping the surrounding air hotter for longer. This value was calculated based on the mitigation of deaths associated with heat stress related illnesses as calculated in the BCE. A benefit number can be calculated to express the value of GSI in the urban landscape based on the estimated value of a statistical life.[xv]

Traffic Calming – Traffic calming techniques such as roundabouts, curb extensions and changes to road environment (such as trees and shrubs) have been shown to reduce the frequency and severity of accidents.[xvi] Following the procedure used by the Autocase tool,[xvii] published Arizona crash rates and associated costs were combined with annual average daily traffic values for Sierra Vista to estimate the potential benefit.

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[i] Assumes half of the rainfall in Las Cruces generates runoff (events greater than 0.1") and the average contributing watershed to GSI features is 7,000 square feet.

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[xi] Business Case Evaluator. http://www.impactinfrastructure.com/businesscaseevaluator/

[xii] Energy Costs of Water (ECW) – U.S. Units: http://www.harvestingrainwater.com/water-energy-carbon-nexus/#Energy Costs of Water

[xiii] Cost adjusted for inflation. http://www.swenergy.org/publications/factsheets/az-factsheet.pdf

[xiv] Oro Valley Storm Water Utility Service Fee Proposal: https://wrrc.arizona.edu/publications/water-harvesting/oro-valley-storm-water-utility-service-fee-proposal

[xv] Impact Infrastructure, Stantec, 2014. Evaluation of GI/LID Benefits in the Pima County Environment, p. 29.

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[xvii] Impact Infrastructure , LLC & Stantec (2014). AutoCASE Beta Testing Project Evaluation of GI/LID in Pima County Environment.