

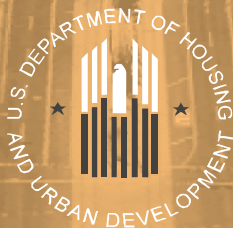
# REINVENT PHOENIX

## GREEN SYSTEMS ASSESSMENT IN THE SOLANO DISTRICT

Partners:



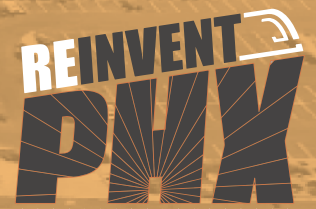
City of Phoenix



St. Luke's Health Initiatives



GLOBAL INSTITUTE  
of SUSTAINABILITY  
ARIZONA STATE UNIVERSITY



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# Assessing the Current State of Green Systems In the Solano District, Phoenix Against Principles of Livability and Sustainability

Report submitted to the City of Phoenix Planning and Development Department by the ASU-SOS Team for the project grant “Reinvent Phoenix – Cultivating Equity, Engagement, Economic Development and Design Excellence with Transit-Oriented Development”, funded by the U.S. Department of Housing and Urban Development (HUD)

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# Executive Summary

The assessment presented in this report indicates that the current green systems conditions in the Solano District are very poor overall. Based on the data collected for this report, residents' perspectives, and the mandate of the U.S. Department of Housing and Urban Development (HUD) there are emergent priorities. Of particular concern are high temperatures, unsustainable water management, and lack of trees. The assessment is based on robust empirical data, despite minor quality issues (a few data gaps and low confidence levels).

Sustainable green systems strives for fully functional stormwater, biodiversity, and resource management practices, as well as sustainable levels of thermal comfort, energy efficiency, and access to green space. The current state assessment is based on four goals of sustainable green systems, derived from sustainability and livability principles (HUD, 2009):

1. Reduce stormwater loads and harvest water on-site
2. Reduce potable water consumption
3. Reduce daytime temperatures
4. Increase green systems benefits to health, mobility, and the economy

A small set of indicators and targets operationalize each goal (see the following summary table). The Solano District struggles with unsustainable states in each of the four goal domains, while there are few positive aspects.

1. *Insufficient stormwater is managed on-site by green systems.* Natural systems capture less than a third of stormwater run-off, and there is nearly no rainwater harvesting in the District.
2. *Sustainability of potable water consumption is low.* Indoor residential potable water use is double sustainable levels, though outdoor use is comfortably within the sustainable range. Given commercial and industrial diversity, water consumption targets for these sectors were unattainable.
3. *Daytime temperatures are very high.* Only 7.8% of Solano has temperatures below 105°F, and high temperatures, asphalt parking, and white roofs all fail to meet sustainable targets. Those areas with high

temperatures worsen the Urban Heat Island (UHI) effect, and cause a variety of health problems.

4. *The health, mobility, and economic benefits of green systems can improve significantly.* The District has no green streets and very low tree canopy cover. Adding green streets, shade, and strategically placed parks to the District would help achieve the preceding goals, as well as improve health, mobility, and the economy.

Detailed assessment results across these goals are in the table that concludes the Executive Summary.

In summary, the District is desperately in need of green systems that reduce daytime temperatures, naturally manage stormwater on-site, and provide safe, cool spaces for citizen recreation and transportation. Thereby, tradeoffs between different green systems features require special attention when crafting sustainable green systems visions and strategies. For example, vegetation that cools and beautifies residential homes also increases water use.

Data from Solano stakeholder engagement efforts confirm that more shade is needed to address concerns about walkability and extreme heat. There is support for shaded green streets that increase walkability, especially along Camelback Road, 15th Avenue, and 19th Avenue. Some residents feel that Solano could improve storm water management in order to further cool the neighborhood, especially in areas that have flood irrigation (parts of Simpson and Washington Park). In concert with safety concerns (Hager et al., 2013), these factors make green systems in Solano insufficient to provide safe and comfortable recreation and mobility for citizens throughout the District. Stakeholder input prioritized temperatures and shade over other concerns.

HUD has operationalized its mandate through *Livability Principles* (2009). Interpreting the assessment results in light of the livability principles indicates the following set of priorities:

Stormwater management, high temperatures, green space, green streets, and shade are indicators that have a high distance to target, and are closely tied to the principles.

- Livability Principle 1 aims at *providing safe transportation options*. The current state data indicates insufficient shade for comfortable bus stops, which may reduce ridership. There are also no green streets in the District.
- Livability Principle 3 aims at *economic competitiveness*. Green systems provide higher quality of life through better health outcomes, increased recreation options, and better urban aesthetics. Current state data shows low tree canopy cover and no green streets, leading to economic disadvantages relative to places with more robust green systems.
- While Livability 6 aims at *valuing communities and neighborhoods*. Current state data for the Solano District paint an un-shaded, hot, un-walkable picture, in direct contradiction to HUD’s wish to “invest in healthy, safe, walkable neighborhoods.”

Finally, the analysis of the driving forces behind the unsustainable states summarized above suggest a variety of economic, social, legal, and other promising intervention points. These insights were used to craft the Sustainable Green Systems Strategy Report for the Solano District.

The assessment table below uses a color rating system. Red indicates that existing conditions fall well short of the sustainable target. Orange indicates that existing conditions fall short of the sustainable target. Yellow indicates that existing conditions are nearing the sustainable target. Green indicates that existing conditions either meet or exceed the sustainable target. Gray indicates that threshold or data is not available (NA).

Summary table of indicators, targets, current data, and assessments [For details see Chapters 3 & 4]

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Goal 1 – Reduce stormwater loads and harvest water on-site							
Natural stormwater runoff capture	High	31.7%	High	>90%	Low	58.3% / High	Red
Rainwater harvesting	Med	Minimal	Med	>95%	Med	~90% / High	Red
Goal 2 – Reduce potable water consumption							
Potable water	High	81.7 GPCD	High	<30 GPCD	Med	51.7 GPCD / High	Red
		87.4 GDHH	High	50–150 GDHH	Med	Fulfilled	Green
		34.6 GPJD	High	NA	NA	NA	Gray
Goal 3 – Reduce daytime temperatures							
Surface (>130°F)	High	17.8%	High	<1%	Med	16.8% / High	Red
Temp (<105°F)		7.8%	High	>10%		2.2% / Med	Orange
Asphalt surface parking	Med	15.5%	High	<5%	Low	10.5% / High	Red
White roofs	Low	5.5%	High	>10%	Low	4.5% / Med	Orange
Goal 4 – Increase green systems benefits to health, mobility, and the economy							
Vegetation coverage	High	3.5%	High	25–40%	Med	21.5% / High	Red
Green open spaces	High	40 ft2/person	High	>97 ft2/person	Med	57 ft2/person / High	Red
Green streets	Med	0	High	>2 mi	Low	2mi / High	Red

# Correspondence to Scope of Work

Scope-of-Work Items	Corresponding Report Chapter
Sub-Task 3.1.a: Data Collection	
Building energy use	In progress
Residential water use	Chapters 3.2 & 4.2
Commercial water use	Chapters 3.2 & 4.2
Infrared satellite images	Chapter 4.3
Stormwater facilities	Appendix
3D buildings model	Figure 2; Appendix
Tree inventory	In progress
Surface parking inventory	
Resident input	Vision Report
Sub-Task 3.1.b: Data Analysis	
Percentage of land used for surface parking	Chapter 4.3
Analysis of community input	Vision Report
Sub-Task 3.1.c: GIS Analysis	
Existing stormwater facilities maps	Appendix
Building / structural shade maps	Figure 2; Appendix
Surface parking inventory maps	Chapter 4.3



# Chapter 1 – Introduction

## 1.1. Green systems challenges in the Solano District

The Solano Transit District is between 15th Avenue and 23rd Avenue, from Campbell Avenue up to Rose Lane East of 19th Avenue, and Keim Drive West of 19th Avenue (Figure 1).



Figure 1. Solano Transit District major streets and landmark

Land use in Solano consists largely of building footprints and parking areas, with some patches of landscaped area or vegetation. Thus, the District is confronted with various challenges in achieving sustainable green systems. Stormwater management and efficient water use is of particular concern, because the Valley faces an uncertain water future.

Solano faces high temperatures from the Urban Heat Island (UHI) effect. Using building footprints and heights, Figure 2 shows shade and areas exposed to direct sunlight. In the summer, it is evident that the predominant single-story buildings offer very little shade over the area. The commercial areas in the center and to the east side of the light rail tend to give more shade.



Figure 2. Composite map of summertime shade at 8 AM, 11 AM, 2 PM, and 5PM

For the most part, District markets look similar to the ones depicted below (Figure 3). Most of these sites are single story buildings surrounded by parking lots and streets. The vegetation is limited, which causes hotter surface areas (increasing the UHI effect in these areas) and limits possibilities for sustainable and effective stormwater management.



Figure 3. Asian Market in Solano

Close to I-17, there are multiple car lots in close proximity, mostly made of asphalt and located on Camelback Road, which has five lanes for traffic. There is limited vegetation for shade and no natural stormwater runoff capture. There is a large open green space to the north, but not enough vegetation to alleviate the heat of the vast parking lots.

Just south of the car lots and north of the Westwood Schools, is “Kids Street.” It is a local mural project with an open dirt streetscape and no vegetation for shade. The Westwood schools are both challenge areas and potential asset areas for UHI mitigation. The open asphalt parking and unshaded playgrounds with little vegetation contribute to higher surface temperatures.

Commercial areas across the District have high surface temperatures. Large, open asphalt parking lots radiate heat. Some of these sites (Figure 4) have limited vegetation with adjacent vacant lots. In addition, bus stops close to these sites offer little shade for pedestrians and public transit riders. The combination of asphalt, limited vegetation, and limited shade structures create uncomfortably hot and unwalkable areas. Such areas contribute to large loads of stormwater runoff that can become polluted from toxins found on the paved surfaces.





Figure 4. Vacant lot adjacent to commercial area

Christown Mall and the light rail park and ride create are large hot areas around the mall, which has little storefront vegetation. The area is dominated by open, asphalt parking lots. There are landscaped areas, and a walkway at the park and ride, but unfortunately, these areas are currently too small to mitigate the heat that radiates from the parking lots.

Solano Park is a large asset for UHI mitigation and overall green system development in Solano. The park provides large, open green spaces with mature, high water use trees. The water for the lawn and the vegetative shade creates a cooler environment for people to enjoy being outside. This area is a valuable recreational asset and can serve as a template for the development of future parks and parklets across the Solano District.



Figure 5. Solano Park

Neighborhoods throughout Solano are both areas of high and low surface temperatures. Asphalt streets and yards with little to no vegetation contribute to higher temperatures. However, yards with small plantings, low water use, and immature trees are areas of lower temperatures. Similarly, fully watered yards with mature shade trees lower surface temperatures throughout neighborhoods.



Figure 6. Single family home in Solano

Another area with a mix of challenge and assets is the 9-hole Palo Verde Golf Course, located northeast of Solano. This large green area contributes to lower surface temperatures in the District with the use of widespread vegetation and tree canopy. It opened in 1962 and was sowed with Bermuda grass. However, from an ecological standpoint, although golf courses are cool patches, the use of large amounts of water for irrigation presents a major challenge for sustainable green systems in the area. The large expanse of turf contributes to high commercial water use. The vegetation in this particular golf course is mature and lush, and the plants have high demand for water. Most of the trees are densely clustered around the pond, which is open to the heat of Arizona. In addition, this large open space is fenced and restricted to the public, offering limited benefits for outdoor recreation for Solano residents.

There is only one brownfield in Solano, from a laundromat. The process has moved onto stage two site cleanup, and currently, the site provides limited vegetation. In addition, the parking lot located at the site directs stormwater runoff directly into the Phoenix water management system, potentially carrying large loads of pollution into the system.

In general, the Solano District hosts a diverse mix of areas of challenges and opportunities for green system development. Some neighborhoods provide areas of potential development for shaded pathways to create cool, walkable neighborhoods. Green spaces throughout the District provide areas of value for UHI mitigation, recreational opportunities, and biodiversity support. Vacant lots scattered throughout the District contribute to higher surface temperatures due to sparse vegetation but also provide areas of opportunity for the development of small parks and open spaces for Solano residents.

## 1.2. Profile of the “Reinvent Phoenix” grant

“Reinvent Phoenix” is a City of Phoenix project in collaboration with Arizona State University and other partners, and funded through HUD’s Sustainable Communities program. This program is at the core of HUD’s mission to “create strong, sustainable, inclusive communities and quality affordable homes for all.” It specifically strives to “reduce transportation costs for families, improve housing affordability, save energy, and increase access to housing and employment opportunities” and to “nurture healthier, more inclusive communities” (Office of Sustainable Housing and Communities, 2012). The program explicitly incorporates principles and goals of sustainability/livability (HUD/DOT/EPA, 2009):

1. Enhance economic competitiveness
2. Provide more transportation choices
3. Promote equitable, affordable housing
4. Support existing communities
5. Coordinate and leverage federal policies and investment
6. Value communities and neighborhoods.

In this spirit, from 2012–2015, Reinvent Phoenix aims to create a new model for urban development in Phoenix. The goals for this new model are to improve quality of life, conserve natural resources, and maintain desirability and access for the entire spectrum of incomes, ages, family sizes, and physical and developmental abilities along the light rail corridor. Reinvent Phoenix aspires to eliminate physical and institutional barriers to transit-oriented development. To do so, the grant will work to catalyze livability and sustainability through capacity building, regulatory reform, affordable housing development, innovative infrastructure design, economic development incentives, and transformational research and planning.

Participatory research design ensures that a variety of stakeholder groups identify strategic improvements that enhance safe, convenient access to fresh food, healthcare services, quality affordable housing, good jobs, and education and training programs. Reinvent Phoenix focuses on six topical elements: economic development, green systems, health, housing, land use, and mobility

(corresponding to the Livability Principles). These planning elements are investigated in five transit Districts (from east to west and south to north): Gateway, Eastlake-Garfield, Midtown, Uptown, and Solano. Planning for the Downtown District of the light rail corridor is excluded from Reinvent Phoenix because of previously completed planning efforts, partly using transit-oriented development ideas.

Reinvent Phoenix is structured into planning, design, and implementation phases. The project’s planning phase involves building a collaborative environment among subcontracted partners, including Arizona State University, Saint Luke’s Health Initiatives, Discovery Triangle, the Urban Land Institute, Local First Arizona, Duany Plater-Zyberk & Company, Sustainable Communities Collaborative, and others. While the City of Phoenix coordinates these partnerships, Arizona State University and Saint Luke’s Health Initiatives are working with residents, business owners, landowners, and other relevant stakeholders in each of the grant’s five transit Districts. This effort will assess the current state of each District, as well as facilitate stakeholder expression of each District’s sustainable vision for the future. Finally, motivated actors in each District will co-create step-by-step strategies to move toward those visions. Transit District Steering Committees, formed in the planning phase, will host capacity building for their members, who will shepherd their Districts through the remaining Reinvent Phoenix phases.

City of Phoenix staff and Duany Plater-Zyberk & Company will lead the design phase. Designs for canal activation, complete streets, and form-based code will complement the compilation of a toolbox for public-private partnerships to stimulate economic development along the light rail corridor. The design phase will take its cues from the public participation in the planning phase, and maintain ongoing monthly contact with Transit District Steering Committees to ensure the visions of each District are accurately translated into policy and regulations. These steps will update zoning, codes, regulations, and city policies to leverage the new light rail system as a major asset. The design phase is crucial for preparing an attractive environment for investment and development around the light rail.

Finally, the implementation phase will use the city’s partnerships with the Urban Land Institute, Local First Arizona, and Sustainable Communities Collaborative to usher in a new culture of development in Phoenix. With the help of all partners, transit-oriented development can be the vehicle to renew Phoenix’s construction industry,

leverage the new light rail system as a major asset. The design phase is crucial for preparing an attractive environment for investment and development around the light rail.

Finally, the implementation phase will use the city's partnerships with the Urban Land Institute, Local First Arizona, and Sustainable Communities Collaborative to usher in a new culture of development in Phoenix. With the help of all partners, transit-oriented development can be the vehicle to renew Phoenix's construction industry, take full advantage of the light rail as a transformative amenity, and enrich Phoenix with a livable and dynamic urban fabric.

### 1.3. Sustainable green systems research in the District

One sub-project of Reinvent Phoenix focuses on green systems and aims to develop *fully functional stormwater, biodiversity, and resource management practices, as well as sustainable levels of thermal comfort, energy efficiency, and access to green space* along the light rail. The green systems project fully aligns with HUD's Sustainable Communities program goals, as stated above (see Livability Principles No. 4 & 6, above).

Sustainable green systems is specified in the following four goals:

1. Reduce stormwater loads and harvest water on-site
2. Reduce potable water consumption
3. Reduce daytime temperatures
4. Increase green systems benefits to health, mobility, and the economy

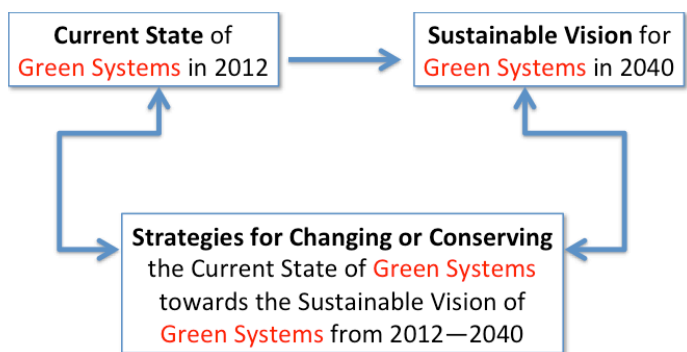


Figure 7. Transformational planning framework (Source: Wiek, 2009)

In pursuit of these goals, we employ a transformational planning framework (Wiek, 2009; Johnson et al., 2011), conducting sustainable green systems research in three linked modules. We start with a thorough assessment of the current state of green systems in the District in 2010/2012 against principles of livability and sustainability (current state assessment); in parallel, create and craft a sustainable vision for green systems in 2040 (visioning); and finally develop strategies for changing or conserving the current state of green systems towards the sustainable vision of green systems between 2012 and 2040 (strategy building). The framework is illustrated below.

Because of the close link between green systems and other planning elements, and the broad impacts of green systems, the central meaning of green systems often remains poorly defined in green systems assessments. Green systems employ natural elements to perform ecosystem services, such as stormwater management, microclimate modification, and improvement of air and water quality, among others (Benedict & McMahon, 2006; Rouse & Bunster-Ossa, 2013). They include building footprints, rights-of-way, public streets, parking areas, landscaping, vegetation, stormwater, water use, and shade patterns affecting local climate conditions. As articulated in Phoenix's tree and shade master plan: Green systems are the interconnected web of parks, streets and canals that help to sustain an active, cool and healthy city. Green systems range from passive water harvesting to porous pavers. Green systems come in a variety of forms from street trees to a large District park. Green systems provide a myriad of economic, social and environmental benefits. Green systems help to reduce energy costs; improve air quality; strengthen quality of place and the local economy; reduce storm water; improve social connections; promote smart growth and compact development; and create walkable neighborhoods. Green systems are solution multipliers that solve many problems with one single investment (2010). According to the U.S. Environmental Protection Agency, "Green infrastructure is an approach that communities can choose to maintain healthy waters, provide multiple environmental benefits, and support sustainable communities. Unlike single-purpose gray stormwater infrastructure, which uses pipes to dispose of rainwater, green infrastructure uses vegetation and soil to manage rainwater where it falls. By weaving natural processes into the built environment, green infrastructure provides not only stormwater management, but also flood mitigation, air quality management, and much more" (2013). With the intent to avoid duplications, overlap, and confusion, we follow in this assessment



report the following definition: *green systems use both natural and engineered systems to provide ecosystem services in a given District* (Cook, 2007).

## 1.4. Objectives of the current state assessment

The current state assessment is a structured procedure that creates a detailed and normative account of the existing conditions of green systems in the District, informed by livability and sustainability principles. The assessment creates a solid foundation and reference point for the strategy building process to achieve sustainable green systems in the District, which is documented in Golub et al. (2013).

Unlike conventional green systems assessments, which are largely descriptive and analytical, the research documented here is functionally linked to the strategy-building module. Conventional assessments often provide a large number of arbitrary data sets, with unclear reference to the main issues being analyzed. They also tend to lack a meaningful normative reference against which the data is being assessed. In this report, there are transparent indications and justifications of the degree of sustainability or unsustainability of the current state of green systems. In accordance with the mandate of Reinvent Phoenix to contribute to sustainable community development, adapt to rising temperatures, increase resiliency to climate change, and improve energy- and water-efficiency of buildings and infrastructure, this report takes an explicit *normative* perspective on green systems, based on sustainability and livability principles (Gibson, 2006; HUD/DOT/EPA, 2009).

Contrary to conventional assessment practice, this report only presents information that can directly be linked to the key guiding question of the green systems assessment: How sustainable/unsustainable is the current state of green systems in the District?

We have excluded from this *current state* assessment report all issues that pertain to *future developments* of green systems in the District. The issue of green systems trends will be addressed in our District green systems strategy report, as it is chiefly concerned with steering that green systems future in a more sustainable and livable direction (Golub et al., 2013).

The core objectives of this current state assessment are:

1. A comprehensible set of goals for sustainable green systems
2. A comprehensible set of performance indicators that operationalize the goals and facilitate detailed description of the current state of green systems
3. Targets for all performance indicators that operationalize the goals and facilitate assessment of the sustainability/unsustainability of the current state of green systems
4. Sustainability assessment of the current state of green systems through comparison of indicators to their identified targets (distance-to-target)
5. Causal problem maps for the performance indicators that identify causal structures and drivers, and thereby suggest promising intervention points for change strategies

Additional objectives include:

1. To develop a process and content template for current state assessment research that can be reproduced in the other four transit Districts and thus guide the Reinvent Phoenix current state assessment activities over the coming years
2. To enhance capacity in current state assessment for planning professionals and collaborating partners to use in subsequent initiatives and projects.
3. To enhance capacity in current state assessment for students and faculty to use in other research, teaching programs, and projects.



# Chapter 2 – Visioning Research Process

## Research Design

The methodological approach employed in this study is based on the transformational planning framework in Figure 7. Following specifications for the current state assessment module, this report pursues the aforementioned objectives through five research streams:

1. Development of an assessment framework composed of normative goals, performance indicators, and targets (Chapter 3)
  - a. Identification of a comprehensible set of goals for sustainable green systems. This research is based on reviewing scientific literature and reference documents (Akbarit et al., 2001; Gibson, 2006; Birch et al., 2008; Giguere, 2009; HUD/TOD/EPA, 2009; Slavin, 2011; Pankiewicz & Ramirez, 2013). Based on this initial review, we synthesized a large number of goals into a smaller set through systematic comparison and integration.
  - b. Identification of a cohesive set of performance indicators that operationalize the goals and facilitate detailed description of the current state of green systems. The indicators are largely determined through literature that suggests a clear link between general goals and measurable indicators (Kuchelmeister, 1998; Sovocool et al., 2001; American Forests, 2002; City of Phoenix, 2008; U.K. Department for Environment, Food and Rural Affairs, 2008; USGBC, 2008; Houston Advanced Research Center, 2009; Wang, 2009; Watershed Management Group, 2010; Bryan, in preparation).
  - c. Identification of a target (or range) for each performance indicator that operationalizes the goals and facilitates assessment of the sustainability/unsustainability of the current state of green systems. Indicators facilitate description of the current state through data collection. Yet, they are insufficient for operationalizing the goals of sustainability/livability. This requires targets (one for each indicator) that are discrete (quantitative or qualitative) thresholds (or ranges) that define, all together, sustainable green systems (Wiek & Binder, 2005; Rockström et al.,

2009; Machler et al., 2012). Due to insufficient research, this is often tedious and challenging (Hoernig & Seasons, 2004). For indicators lacking firm targets or thresholds in the literature, we rely on our team's expert opinions to make reasonable estimates. Indicators without clear targets are labeled as "not available" (NA).

2. Assessment of the sustainability/unsustainability of the current state of green systems based on comparison of current state data (for each indicator) to the identified targets (distance-to-target). This shows how sustainable/unsustainable the current state of green systems is in specific (for each indicator) and overall (aggregated) (Chapter 4).
3. Identification of the causal structure (drivers) of performance indicators, which reveals promising intervention points for change strategies. Causal assumptions are based on expert input and scientific literature; and, a system analysis explores linkages among all the indicators (Vester, 2008; Wiek et al., 2008). The final step defines the linkages between green systems indicators quantitatively (strength of impact) and qualitatively (type of impact). Causal structure analysis is critical for strategy building, because performance indicators cannot be directly changed. Sustainable green systems strategies must change the upstream drivers of indicators, which requires detailed knowledge of causal linkages (Chapter 5).

## Data Sources

Data for this assessment come from a variety of sources. The City of Phoenix provided public geographical data for land use, zoning, and other infrastructure, and the city water department provided water consumption data. Electricity usage data is still being processed.

The Central Arizona–Phoenix Long-Term Ecological Research (CAP-LTER) program (National Science Foundation grant BCS-1026865) made land cover (porosity) and MASTER remote sensing data available. The MASTER data for surface temperatures is a daytime image from July 12th, 2011. Our research team processed temperature information from the data, and created distributions and averages for census block group

geography to insure compatibility with other maps. This allowed us to calculate the percent of surface area in the District within certain temperature ranges.

For some indicators, no data is available and they are marked “ND” accordingly. They remain in our assessment with the hope that data will become available in the future, and facilitate further assessment.

# Chapter 3 – Sustainable Green Systems Goals, Indicators, and Targets

Livability and sustainability are core framing concepts for HUD’s Sustainable Communities program, and therefore, the Reinvent Phoenix project. As stated in Chapter 1, we follow in this assessment report the following definition of green systems: *green systems use both natural and engineered systems to provide ecosystem services in a given District* (Cook, 2007). Green systems are *not* inherently sustainable in their design and outcomes. For example, a greenway that runs through a neighborhood (which can be described as a feature of a green system) that uses impermeable surfaces and little plant diversity does not produce a system that effectively harvests stormwater on-site and encourages biodiversity and overall water conservation. Thus, we employ a specific definition of *sustainable green systems*, which require *fully functional stormwater, biodiversity, and resource management practices, as well as sustainable levels of thermal comfort, energy efficiency, and access to green space*. These elements must all be present to create a sustainable green system. In other words, the system must seek to harvest stormwater on-site, encourage a diverse range of fauna and flora, reduce overall resource use (e.g. water and energy), reduce overall temperatures in urban environments, and provide access for all people to high quality green spaces. This chapter details the key features of sustainable green systems, based on sustainability and livability literature. It also defines indicators and targets for four sustainable green systems goals (Akbarit et al., 2001; Gibson, 2006; Birch et al., 2008; Giguere, 2009; HUD/TOD/EPA, 2009; Slavin, 2011; Pankiewicz & Ramirez, 2013):

1. Reduce stormwater loads and harvest water on-site
2. Reduce potable water consumption
3. Reduce daytime temperatures
4. Increase the health, mobility, and economic benefits of green systems

Recent research indicates that these goals are best pursued in concert, as they offer synergies among them (Birch et al., 2008; Pankiewicz, 2013).

## 3.1. Goal 1 – Reduce stormwater loads and harvest water on-site

Table 1. Indicators and targets of sustainable stormwater loads and water harvesting

Indicator	Definition	Importance	Sustainability Target (Range)	Confidence Level T.
Natural stormwater runoff capture	Percentage of permeable land	High	>90% <sup>A</sup>	Low
Rainwater harvesting	Percentage of buildings with rainwater harvesting systems	Med	>95% <sup>A</sup>	Med

References and Notes:

- A. Center for Watershed Protection, 2010; Watershed Management Group, 2010

With average annual precipitation of only 5–10 inches, Phoenix has significant incentive to harness water resources that are otherwise lost. Traditional stormwater management practices use impermeable surfaces, such as roads, curbs, and culverts, to divert large quantities of water into centralized infrastructure. This draws pollution and debris into the infrastructure, with negative effects on water quality (Cook, 2007; Gautam et al., 2010). These traditional stormwater management systems increase flooding, pollute surrounding bodies of water, degrade natural habitats, and increase health risks and maintenance costs.

Alternatively, green stormwater management systems use trees, rocks, and vegetation to harvest, treat, and store stormwater runoff. These green systems percolate water into permeable soil to support vegetation, and reduce stormwater burden on sewage and other infrastructure. Soil design (i.e. types of soil, depth of soil beds, etc.) can improve pollutant filtering and increase water percolation for the overall success of the system (Scheyer & Hipple,

2005). Green stormwater management systems are cost-effective and environmentally friendly (Cook, 2007).

To augment green stormwater management systems, rainwater-harvesting systems pipe roof runoff to barrels or downspouts, and then filter and chemical/UV treat the water to use for drinking. Complex rainwater-harvesting systems store water in extensive cistern systems for indoor and outdoor uses (drinking water is further filtered and treated) (Oregon Department of Consumer Business and Services, 2013). Stormwater management and water harvesting technologies allow greater water penetration into the ground, and reduce flood risk and water use.

### 3.2. Goal 2 – Reduce potable water consumption

Table 2. Indicators and targets of sustainable potable water consumption

Indicator	Definition	Importance	Sustainability Target (Range)	Confidence Level T.
Potable water	Average indoor residential use	High	<30 GPCD <sup>A</sup>	Med
	Average outdoor residential use <sup>B</sup>	High	50 – 150 GDHH <sup>C</sup>	Med
	Average industrial and commercial use	High	NA	NA

References and Notes:

- B. 90by20.org (2013); gallons per capita per day
- C. Outdoor data was not available, so winter water use was used as a baseline, and excess water used in the summer was assumed to be for outdoor landscaping use.
- D. 50 gallons per day per household (GDHH) was estimated to be reasonable summer water consumption to maintain a ¼-acre lot with trees and minimal landscaping during the summer months. Above 150 GDHH would be incompatible with the water consumption target in Chapter 3.4 of the District Housing Assessment Report (2013).

Potable water consumption includes indoor residential, landscaping and irrigation, and industrial and commercial uses. Reduction of potable water consumption conserves a valuable natural resource in a desert climate. Prominent potable water conservation practices include the rainwater harvesting systems mentioned, and changes in behavior (i.e. personal conservation habits).

There is a conflict between reduced water use and the green space of Goal 4. For example, lower water use is good for water conservation, but higher water use is good for green space and reducing temperatures. If density increases with people moving into apartments and condominiums, average household water use will decrease with smaller outdoor and indoor areas. However, more people might mean more total water use. This tradeoff will be further explored in the subsequent strategy document for the District.

### 3.3. Goal 3 – Reduce daytime temperatures

Table 3. Indicators and targets of sustainable daytime temperatures

Indicator	Definition	Importance	Sustainability Target (Range)	Confidence Level T.
Surface temp.	Percentage of District >130°F	High	<1% <sup>A</sup>	Med
Asphalt surface parking	Percentage of District <105°F	Med	>10% <sup>A</sup>	Low
White roofs	Percentage of District that is black asphalt surface parking	Med	<5% <sup>B,C</sup>	Low
	Percentage of District that has white roofs	Med	>10% <sup>C</sup>	Low

References and Notes:

- A. Authors' best estimates based on Bryan, 2001.
- B. Of off-street parking
- C. Authors' best estimates



Phoenix recognizes that thermal comfort is key for the success of Downtown (City of Phoenix, 2008). In a city where outdoor summertime temperatures exceed 110°F, the Urban Heat Island (UHI) effect is a major concern. UHI refers to “hot spots” and higher surface temperatures where exposed pavement and building materials absorb solar energy, creating higher surface temperatures (Stone et al., 2001; Carlson et al., 2008; Houston Advanced Research Center, 2009). Increased temperatures can lead to cardiovascular stress, heat stress, and heat strokes, as well as higher risks of respiratory distress syndrome, kidney and liver failure, and death (Kleerekoper et al., 2012). In general, young children, people with chronic diseases, and the elderly have the highest risk for heat related illnesses (Giguere, 2009).

UHI also increases the demand for air conditioning and cooling, which in turn increases water use for electricity production. Extra energy production to combat UHI accelerates ground level ozone formation, and emits carbon monoxide, carbon dioxide, sulfur dioxide, nitrogen oxide, mercury, and particulate matter into the atmosphere (Healthy Air Living, 2011). Air pollution from these emissions can decrease lung function and lead to, or worsen, lung inflammation. Higher temperatures also transfer heat to stormwater runoff, increasing stream, lake, and river water temperature by up to 4°F, which significantly decreases water quality (Wong, 2013).

The most common strategies for mitigation of UHI are vegetation, shade structures, and cool materials in built infrastructure (Giguere, 2009). Vegetation cover increases biodiversity, reduces cooling demand, and improves stormwater management (Susca et al., 2011). Cool roofs use light-colored or white roofing products, solar roofing systems (Carlson et al., 2008), or reflective elastomeric or polyurea membrane coatings, which reduce temperatures on roofs by reflecting sunlight away (Giguere, 2009).



Figure 8. Maintained and irrigated vegetation and lawn (Source: Kimpel & Butler)

Bus stops, covered parking, public kiosks, and gazebos can add shade and help reduce surface temperatures. Cool pavements also help, by using materials that change absorption, storage, and radiation of heat. Such pavements can decrease surface temperatures by up to 7°F (Pomerantz et al., 2000). Vegetation on private land, along streets, and in community gardens, parks, and seasonal shading structures increases evapotranspiration and minimizes ground temperatures. This leads to lower surface temperatures, improved air and water quality, and better quality of life (Giguere, 2009).



Figure 9. Covered parking (Source: Kimpel & Butler)

### 3.4. Goal 4 – Increase green systems benefits to health, mobility, and the economy

Table 4. Indicators and targets of increasing green systems benefits to health, mobility, and the economy

Indicator	Definition	Importance	Sustainability Target (Range)	Confidence Level T.
Vegetation coverage	Percentage of District covered by trees	High	25–40% <sup>A</sup>	Med
Green open spaces	Ft <sup>2</sup> /person of parks, urban forests, and green open space	High	>97 ft <sup>2</sup> /person <sup>B</sup>	Med
Green streets	Mi of green streets/mi <sup>2</sup>	Med	2 mi <sup>C</sup>	Low

References and Notes:

- A. City of Phoenix, 2010
- B. Kuchelmeister, 1998; American Forests, 2002; City of Phoenix, 2008; Wang, 2009; Beatley, 2011
- C. Author's best estimates

Non-shaded pavement and rooftops have higher temperatures (Stone et al., 2001; Carlson et al., 2008; Houston Advanced Research Center, 2009). Green streets reduce temperatures by adding shade structures and vegetation to sidewalks and parking lots to reduce temperatures where people walk or wait for public transit. Shade, parks, and living green environments provide opportunities for shaded outdoor recreation and activity, and have physical and mental health benefits (Ulrich, 1984; DeVries et al., 2003).



Figure 10. Wildlife (Source: Kimpel & Butler)

The integration of wild or semi-wild nature into cities supports biodiversity (Beatley, 2010; Faeth et al., 2011), which is essential for human health (Chivian & Bernstein, 2008). Safe, comfortable pedestrian and bike mobility is imperative for a city to thrive, and is directly tied to the quantity and quality of green systems. Residents are more likely to use bike and pedestrian paths for recreation and transportation when they are safe and cool. Green spaces and vegetation create these comfortable and cool routes that expand mobility options beyond expensive personal automobile travel. A flourishing urban forest is critical for the social, economic, and environmental health of a city. Air temperature data from Portland, OR found that the most important characteristic separating warmer from cooler urban areas was tree canopy cover, regardless of the time of day (Hart et al., 2009)



Figure 11. Shaded walkways (Source: Kimpel & Butler)

Urban forests improve the quality of urban life in many ways (Kuchelmeister, 1998). Phoenix recognizes the importance of investing in urban forest, and notes in their Tree & Shade Master Plan (City of Phoenix, 2010) that such investment can clean the air, increase biodiversity, address UHI, decrease energy costs, increase property values, and reduce stormwater runoff and Phoenix's carbon footprint.

### 3.5. Summary

The following overarching questions, based on the sustainability goals above, guide the assessment of green systems sustainability in the District (Chapter 4):

1. Does current stormwater infrastructure adequately capture water on-site and in the right-of-way (RoW), using soil, porous surfaces, trees, and other types of vegetation?
2. Is potable water use efficient (landscaping, residential, commercial, and industrial)?
3. Are outdoor surface temperatures low enough for pedestrian and cyclist comfort?
4. Are cool or green roofs reducing heat gain in buildings?
5. Is there enough shade and tree canopy to reduce air temperatures?
6. Is there equitable access to public green space?
7. Is there adequate natural environment available to conserve and protect native biodiversity?

This chapter concludes with an overview table that summarizes all relevant information presented in detail above. Table 5 could be used as a checklist for green systems assessments.

Table 5. Summary of sustainability goals, indicators, and targets

Indicator	Definition	Importance	Sustainability Target (Range)	Confidence Level T.
<b>Goal 1 – Reduce stormwater loads and improve quality of stormwater runoff</b>				
Natural stormwater runoff capture	Percentage of permeable land	High	>90%	Low
Rainwater harvesting	Percentage of buildings with rainwater harvesting systems	Med	>95%	Med
Stormwater quality	Pollution level	High	ND	Low
<b>Goal 2 – Reduce potable water consumption</b>				
Potable water	Average indoor residential use	High	<30 GPCD	Med
	Average outdoor residential use	High	50–150 GDHH	Med
	Average industrial and commercial use	High	NA	NA
<b>Goal 3 – Reduce daytime temperatures</b>				
Surface temperatures	Percentage of District >130°F	High	<1%	Med
	Percentage of District <105°F		>10%	
Asphalt surface parking	Percentage of District that is black asphalt surface parking	Med	<5%	Low
White roofs	Percentage of District that has white roofs	Med	>10%	Low
<b>Goal 4 – Increase green systems benefits to health, mobility, and the economy</b>				
Vegetation coverage	Percentage of District covered by trees	High	25–40%	Med
Green open spaces	Ft <sup>2</sup> /person of parks, urban forests, and green open space	High	>97 ft <sup>2</sup> /person	Med
Green streets	Mi of green streets/mi <sup>2</sup>	Med	>2 mi	Low

# Chapter 4 – Sustainability of the Current State of Green Systems

In this chapter, we present the sustainability assessment of the current state of green systems in the Solano District, based on the goals, indicators, and targets presented in Chapter 3. Data was gathered from the most recent sources available, as discussed in Chapter 2. The assessment uses a color rating system. Red indicates that existing conditions fall short of the sustainable target. Green indicates that existing conditions either meet or exceed the sustainability target. Gray indicates that an explicit threshold is not available (NA), or there is no data available (NA) for that indicator.

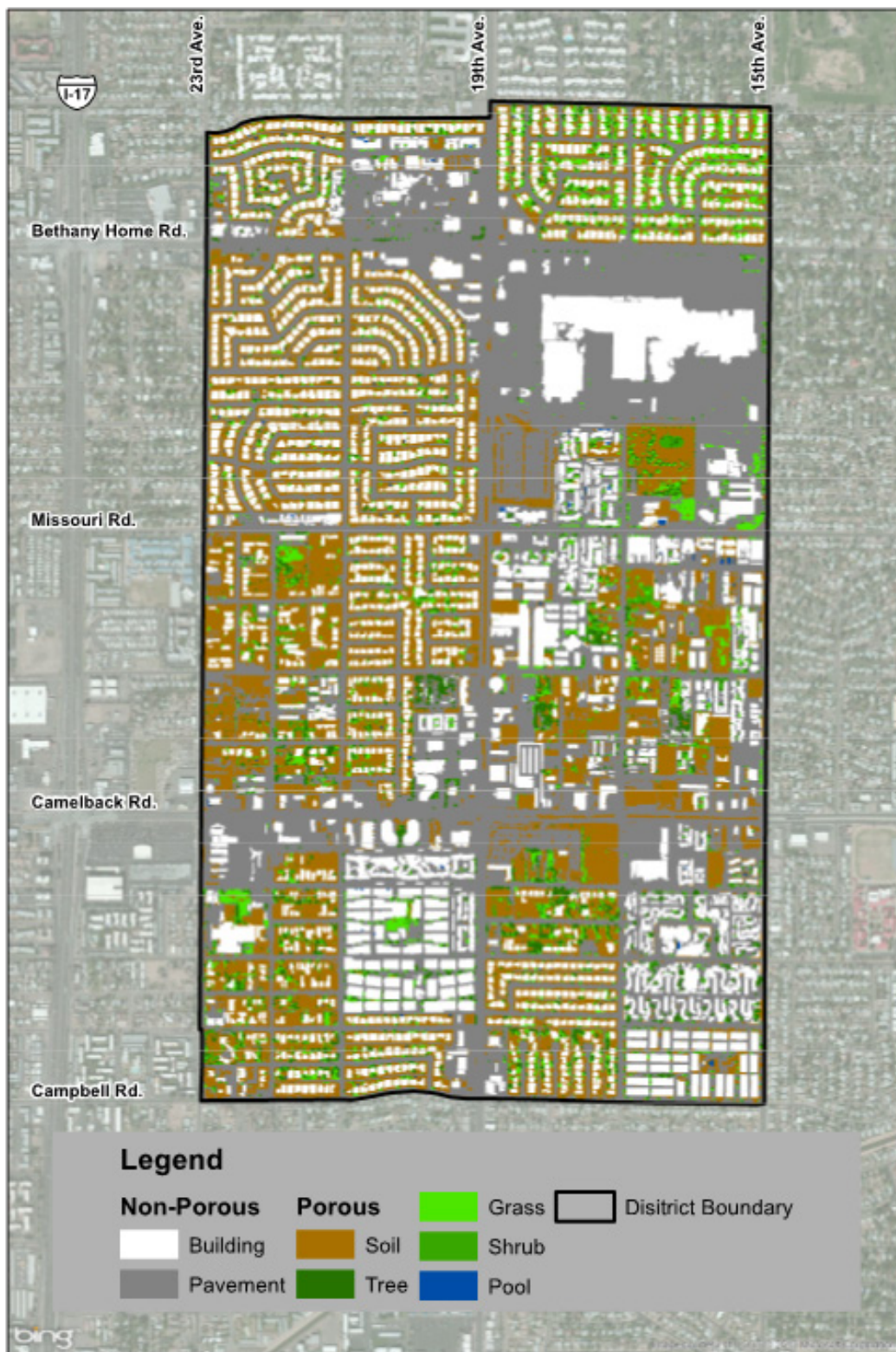
## 4.1. Goal 1 – Current state of reducing stormwater loads and harvesting water on-site

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Natural stormwater runoff capture	High	31.7%	High	>90%	Low	58.3% / High	
Rainwater harvesting	Med	Minimal	Med	>95%	Med	~90% / High	

### Current State Data

More than 65% of Solano’s surface is impervious (Figure 11), making on-site storage of stormwater a large challenge. Data for rainwater harvesting was not available, though we suspect it is fairly low or nonexistent.





## Reinvent PHX

### Solano District

### Material Porosity

0 0.5 Miles  
1 inch = 833 feet

Figure 11. Surface porosity

## Assessment

The literature does not specify a sustainability threshold for percentage of stormwater runoff captured by trees and vegetation. However, it is clear that substantial water is lost due to lack of natural stormwater management practices and the low percentage of permeable land. One 8.5 x 20 foot asphalt parking space generates about 100 gallons of runoff in a one-inch storm (Watershed Management Group, 2010). Extrapolating to the District level, during a one-inch storm, Solano’s buildings and pavement respectively produce around 7.3 and 12 million gallons of runoff, for a total of 19.3 million gallons of runoff. This would be sufficient for 10 days of District potable water consumption, based on Solano’s 1.8 million gallons per day consumption.

## 4.2. Goal 2 – Current state of reducing potable water consumption

Table 7. Sustainability assessment of potable water consumption

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Potable water	High	81.7 GPCD	High	<30 GPCD	Med	51.7 GPCD / High	
		87.4 GDHH	High	50–150 GDHH	Med	Fulfilled	
		34.6 GPJD <sup>A</sup>	?	NA	NA	?	

Notes and References:

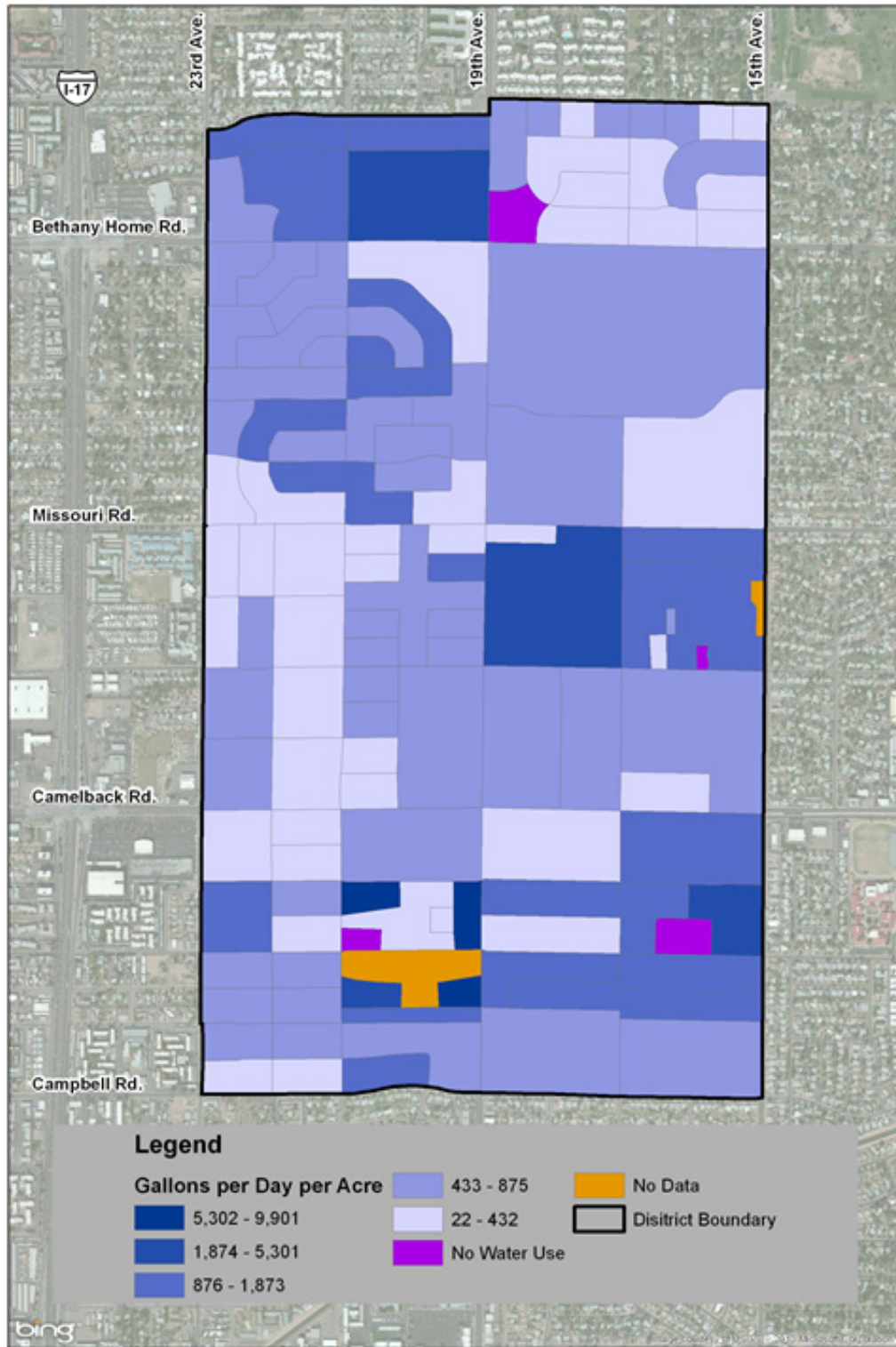
A. Gallons per job per day

### Current State Data

Solano lacks commercial-scale agriculture, making for low overall water use relative to other areas in the region. Thus, most of the assessment data focuses on residential water use. Typical residential water use includes drinking, cooking, bathing, toilet flushing, swimming pools, lawns, gardens, and washing cars, clothes, and dishes (EPA, 2004). The combined residential indoor and outdoor water use in Solano, ~170 GPCD, is about double the U.S. average of 80–100 GDHH (USGS, 2013). The lower cost of water in Phoenix, as well as the presence of many single-family homes with yards, may be the cause of this high number.

### Assessment

Solano’s indoor water use is more than double the sustainable limit, whereas outdoor water use is comfortably within the sustainable threshold. However, such water use may not be sustainable into the future with decreased water availability in the Valley. This presents a trade-off between water conservation and higher water use that improves the local landscape and thermal comfort. These trade-offs are important and will be explored further in the Solano District Green Systems Strategy Report (Wiek, 2013). Distribution of water use in the District is a concern, with many households potentially unable to have enough landscape cover and vegetation to provide thermal comfort from higher temperatures in the summer (Figure 12).




**Reinvent PHX**  
Solano District  
Landscaping Water Use: Summer



Figure 12. Summer outdoor water consumption



The Leadership in Energy and Environmental Design (LEED) rating system has guidelines for summertime irrigation. For a LEED water efficiency credit (i.e. for a sustainable level of irrigation water consumption), potable water consumption for irrigation should be 50% of the mid-summer baseline average for the surrounding area (U.S. Green Building Council, 2005). Because the sustainability guidelines for summertime irrigation practices in arid regions are geared toward specific reduction strategies, it is difficult to assess the current state of water use in Solano. Summer outdoor water use is 87.4 GDHH, which is more than enough to support hybrid desert-adapted landscaping and a small lawn on a 10,000 square foot lot. A lower target is possible, but would cause tradeoffs with thermal comfort and outdoor recreation, as discussed in Chapter 3.3. Because the diversity of industrial and commercial uses makes target setting problematic, there is not sufficient context to assess the sustainability of industrial and commercial use.

### Assessment

The sustainable threshold in Phoenix is around 106°F for outdoor ambient air temperature. As temperatures increase above this threshold, human thermal comfort decreases, and there is increased danger of heat stroke (Bryan, In Preparation). Unfortunately, no good records exist for ambient temperatures, other than at specific weather stations. However, we do have good data on surface temperatures, which seriously exceed acceptable levels with 92.2% of Solano surface temperatures above 105°F (Figures 13 & 14).

The sustainable threshold for asphalt surface parking is <5% of the District. In addition, paving should be at least 50% pervious, and have 29% solar reflectance, to reduce UHI (USGBC, 2009; Bryan, In Preparation). Solano is currently 15.5% asphalt surface parking, which is well above the threshold (Figure 15).

### 4.3. Goal 3 – Current state of reducing daytime temperatures

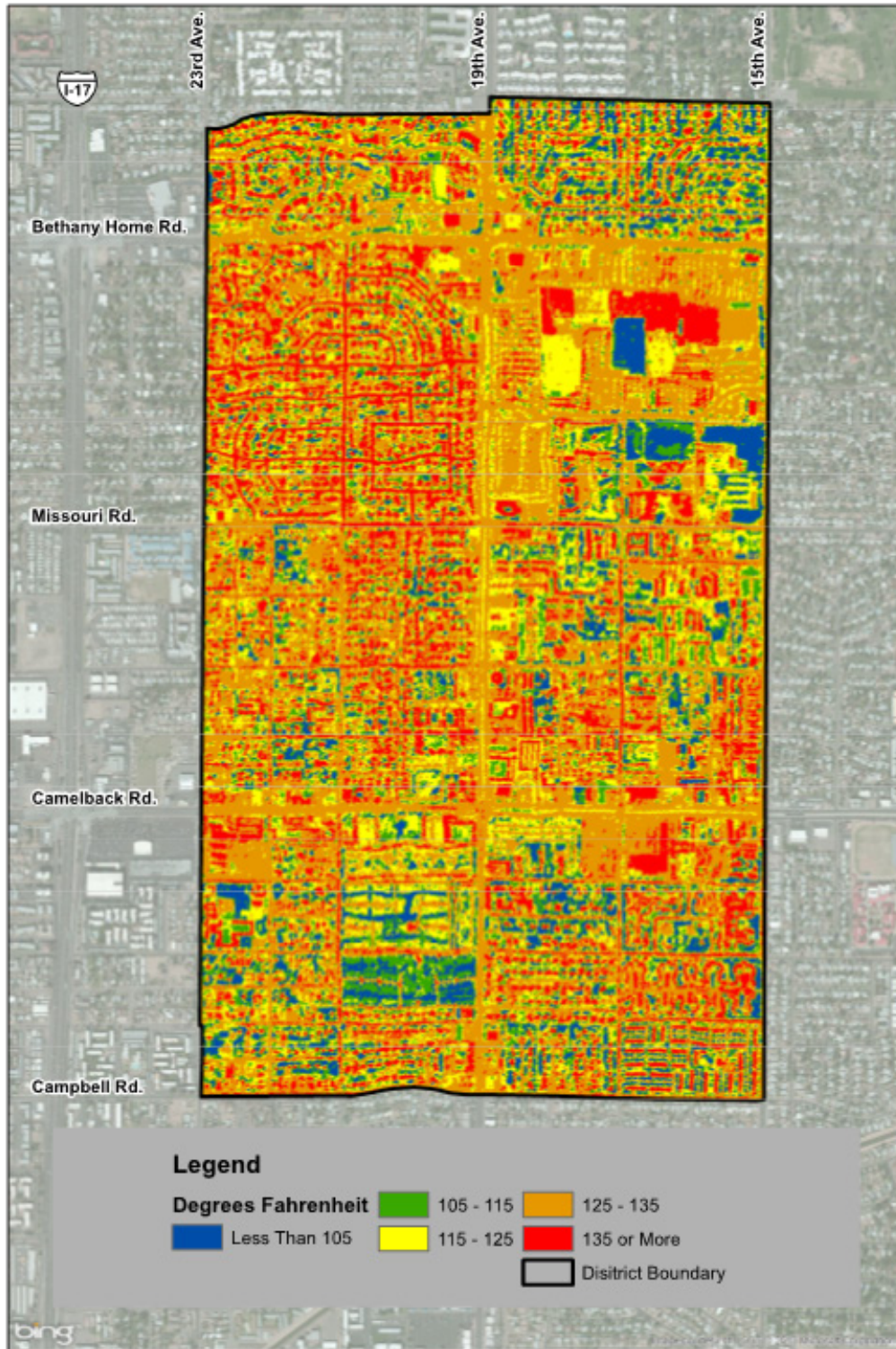
Table 8. Sustainability assessment of daytime temperatures

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Surface temperatures	High	17.8%	High	<1%	Med	16.8% / High	Red
		7.8%		>10%		2.2% / Med	Orange
Asphalt surface parking	Med	15.5%	High	<5%	Low	10.5% / High	Red
White roofs	Low	5.5%	High	>10%	Low	4.5% / Med	Orange

#### Current State Data

Although the translation from surface to ambient air temperatures is not exact, surface temperatures do have strong effects on human thermal comfort. Nearly 20% of Solano has surface temperatures above 130°F, and 74.4% is 105–130°F. Solano is 15.5% asphalt surface parking, which contributes to its high surface temperatures. A slight share of the District, about 6%, has white roofs that reduce building energy use.

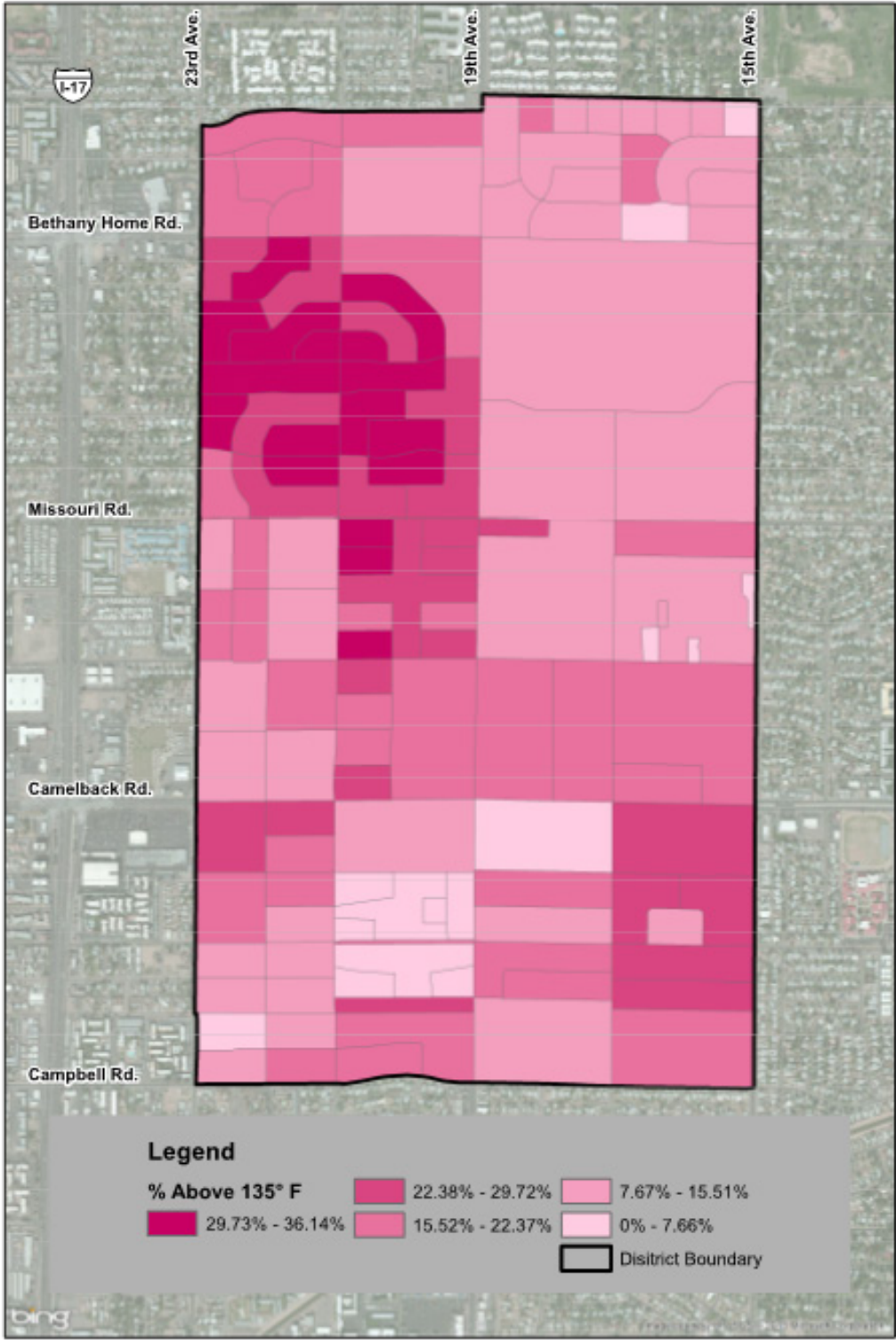




**Reinvent PHX**  
 Solano District  
 July 2012 Temperature



Figure 13. Detailed daytime summer temperature image



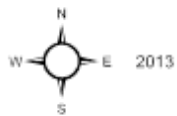
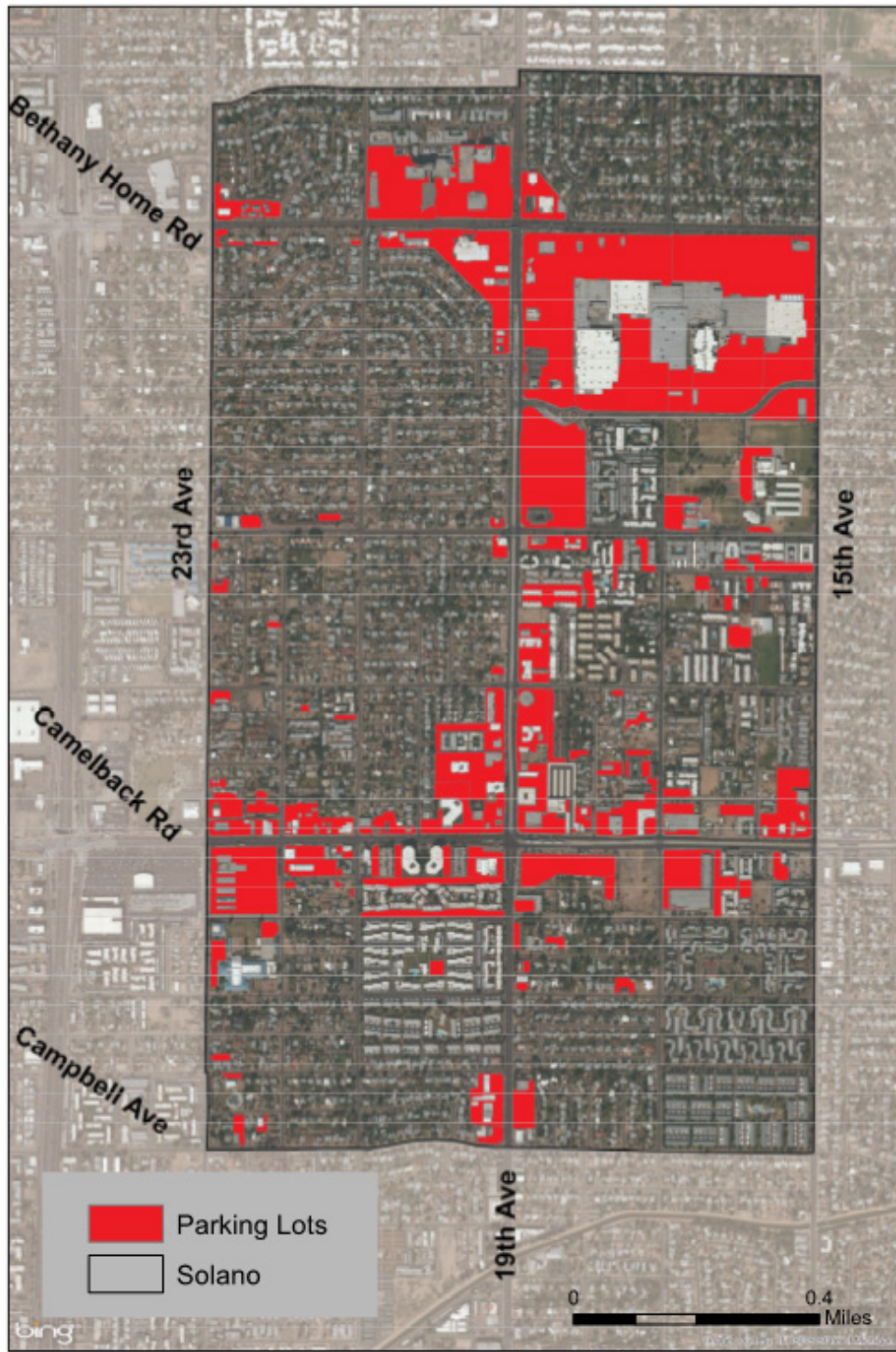
**Reinvent PHX**  
 Solano District  
 Temperature Range: High



Figure 14. Percentage of census block with surface temperatures above 130°F



The sustainable threshold for asphalt surface parking is <5% of the District. In addition, paving should be at least 50% pervious, and have 29% solar reflectance, to reduce UHI (USGBC, 2009; Bryan, In Preparation). Solano is currently 15.5% asphalt surface parking, which is well above the threshold (Figure 15).



## Reinvent PHX

Solano  
Parking Lots

Figure 15. Surface Parking

## 4.4. Goal 4 – Current state of increasing green systems benefits to health, mobility, and the economy

Table 9. Sustainability assessment of increasing green systems benefits to health, mobility, and the economy

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Vegetation coverage	High	3.5%	High	25–40%	Med	21.5% / High	
Green open spaces	High	40 ft <sup>2</sup> / person	High	>97 ft <sup>2</sup> /person	Med	57 ft <sup>2</sup> /person / High	
Green streets	Med	0	High	>2 mi	Low	2 mi / High	

### Current State Data

Solano has only 3.5% vegetation coverage, and merely 40 feet of green space per person. There are no “green streets” or nature preserves open to public use in the District. In addition, much of Solano is impervious (i.e. concrete) and without shade, creating a highly unpleasant pedestrian environment, and providing little to no opportunity for vegetation to increase biodiversity.

### Assessment

High quality green spaces have significant social and economic benefits for neighborhoods. A sustainable percentage of tree canopy cover in semi-arid U.S. cities is 25–30% overall, 35–40% in suburban residential areas, 20% in urban residential zones, and 10% in Central Business Districts (American Forests, 2002). Solano is nowhere near the suggested range of 25–40% tree canopy cover, with only 3.5% of the District covered by trees. This has significant implications for health and biodiversity throughout the District. Without tree coverage, shade is minimal in the area, magnifying the UHI effect and worsening areas of high surface temperatures. These high temperatures have significant impacts on heat-related illness and air quality in the District. The lack of tree coverage also reduces the amount of natural habitats for plant and animal species, limiting overall biodiversity potential for Solano.

The international minimum standard of green open space per city dweller is 97 square feet, and the general standard for developed countries is 215 square feet per person of parkland (Kuchelmeister, 1998; Wang, 2009). Solano is less than half the international minimum standard, indicating a serious lack of green open space for District recreation and biodiversity support.



## 4.5. Summary

We conclude this chapter with an overview table that summarizes all relevant information presented in detail above. Table 10 could be considered the checklist for Solano’s green systems assessment.

Table 10. Summary table of indicators, targets, current data, and assessments

Indicator	Importance	Current State Data	Confidence Level C. S. D.	Sustainability Target (Range)	Confidence Level T.	Distance-to-target	Assessment
Goal 1 – Reduce stormwater loads and harvest water on-site							
Natural stormwater runoff capture	High	31.7%	High	>90%	Low	58.3% / High	Red
Rainwater harvesting	Med	Minimal	Med	>95%	Med	~90% / High	Red
Goal 2 – Reduce potable water consumption							
Potable water	High	81.7 GPCD	High	<30 GPCD	Med	51.7 GPCD / High	Red
		87.4 GDHH	High	50–150 GDHH	Med	Fulfilled	Green
		34.6 GPJD	High	NA	NA	NA	Grey
Goal 3 – Reduce daytime temperatures							
Surface (>130°F)	High	17.8%	High	<1%	Med	16.8% / High	Red
Temp (<105°F)		7.8%	High	>10%		2.2% / Med	Orange
Asphalt surface parking	Med	15.5%	High	<5%	Low	10.5% / High	Red
White roofs	Low	5.5%	High	>10%	Low	4.5% / Med	Orange
Goal 4 – Increase green systems benefits to health, mobility, and the economy							
Vegetation coverage	High	3.5%	High	25–40%	Med	21.5% / High	Red
Green open spaces	High	40 ft <sup>2</sup> /person	High	>97 ft <sup>2</sup> /person	Med	57 ft <sup>2</sup> /person / High	Red
Green streets	Med	0	High	>2 mi	Low	2mi / High	Red

# Chapter 5 – Causal Problem Maps of Green Systems

In this chapter, we present the drivers (causal structures) for the problems identified in the sustainability assessment (Chapter 4). The problem maps are primarily defined through those performance indicators that do not meet their sustainability targets. All causal assumptions are based on expert input and scientific literature. Performance indicators themselves cannot be directly changed, because change requires addressing the upstream drivers of indicators. The causal problem maps identify those drivers, and promising intervention points for strategies of change. (Golub et al., 2013).

## 5.1. Goal 1 – Problem map of reducing stormwater loads and harvesting water on-site

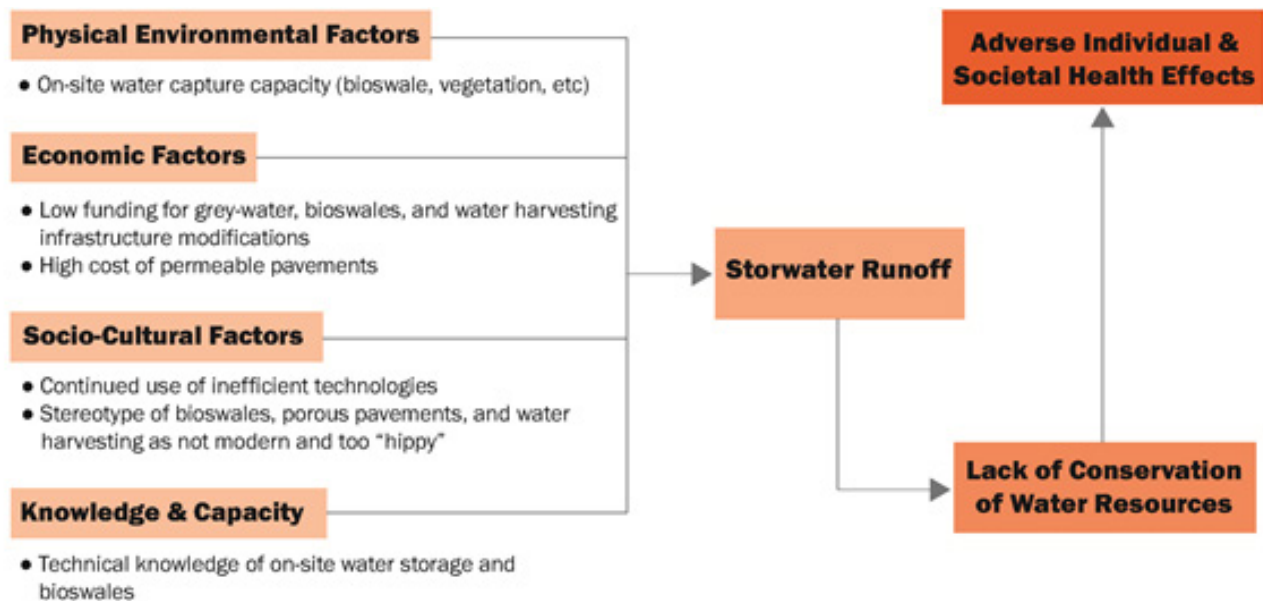


Figure 16. Reduce stormwater loads and harvest water on-site problem map

The major drivers of stormwater management challenges are low funding, high costs, negative perceptions of new technologies, and insufficient technical capacity. Designers and engineers prefer “gray” methods such as non-permeable surfaces in stormwater systems, but costs for construction and maintenance limit implementation of more sustainable technologies. Strategic areas of intervention include funding for green water management systems, and building capacity and desire to build and use those technologies.

## 5.2. Goal 2 – Problem map of reducing potable water consumption

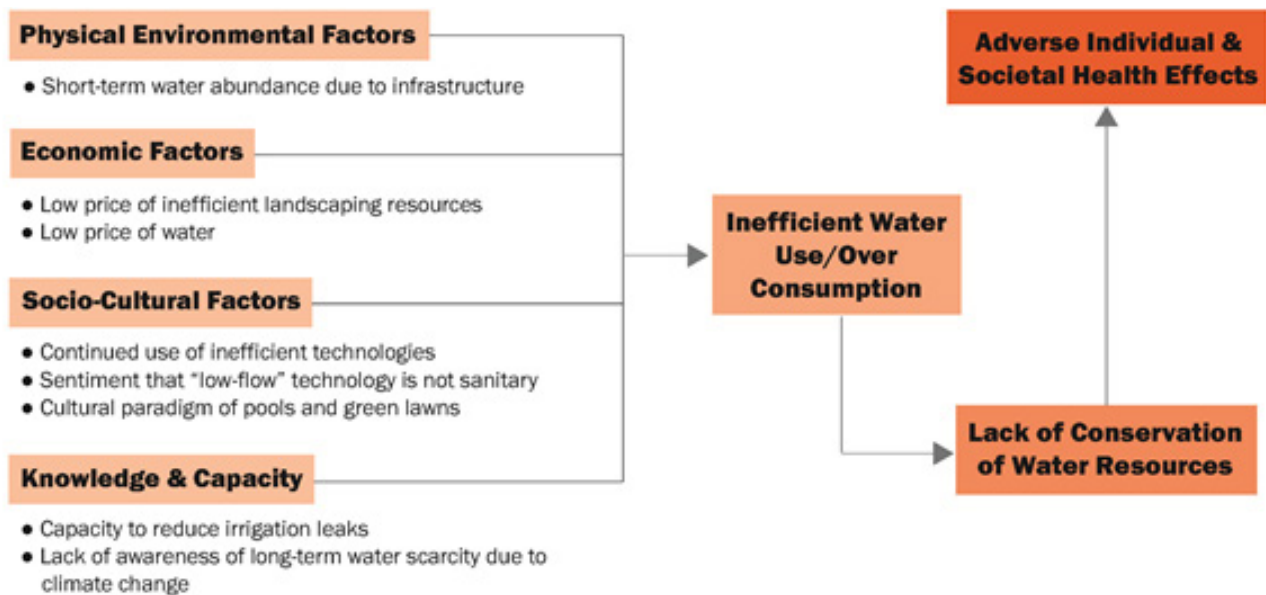


Figure 17. Reduce potable water consumption problem map

In addition to stormwater harvesting, reduction of potable water consumption can aid water conservation. Figure 17 illustrates that water abundance and underpricing in Phoenix encourage high water use. Availability of water-inefficient landscaping resources, such as non-native vegetation and traditional irrigation systems, combine with low prices to drive unsustainable usage rates, especially considering long-term water scarcity due to climate change.

With a population often originating from Midwest or Eastern U.S., cultural preferences for lush landscapes are prevalent, and further pressure limited resources. In addition, negative perceptions of water-saving technologies and insufficient ability to manage irrigation leakage increase water consumption. Often, residents do not know how to water unfamiliar plants and landscaping properly, leading to overwatering. Finally, landscape design often does not use sustainable water consumption as a criterion, leading to water inefficient landscape design. Possible areas of intervention include incentives and rules (city or HOA, etc.) that encourage native, drought-tolerant vegetation, and outreach to build knowledge and capacity about landscape design, water conservation technologies, and long-term water shortage risks.

## 5.3. Goal 3 – Problem map of reducing daytime temperatures

### 3. Reduce Daytime Temperatures

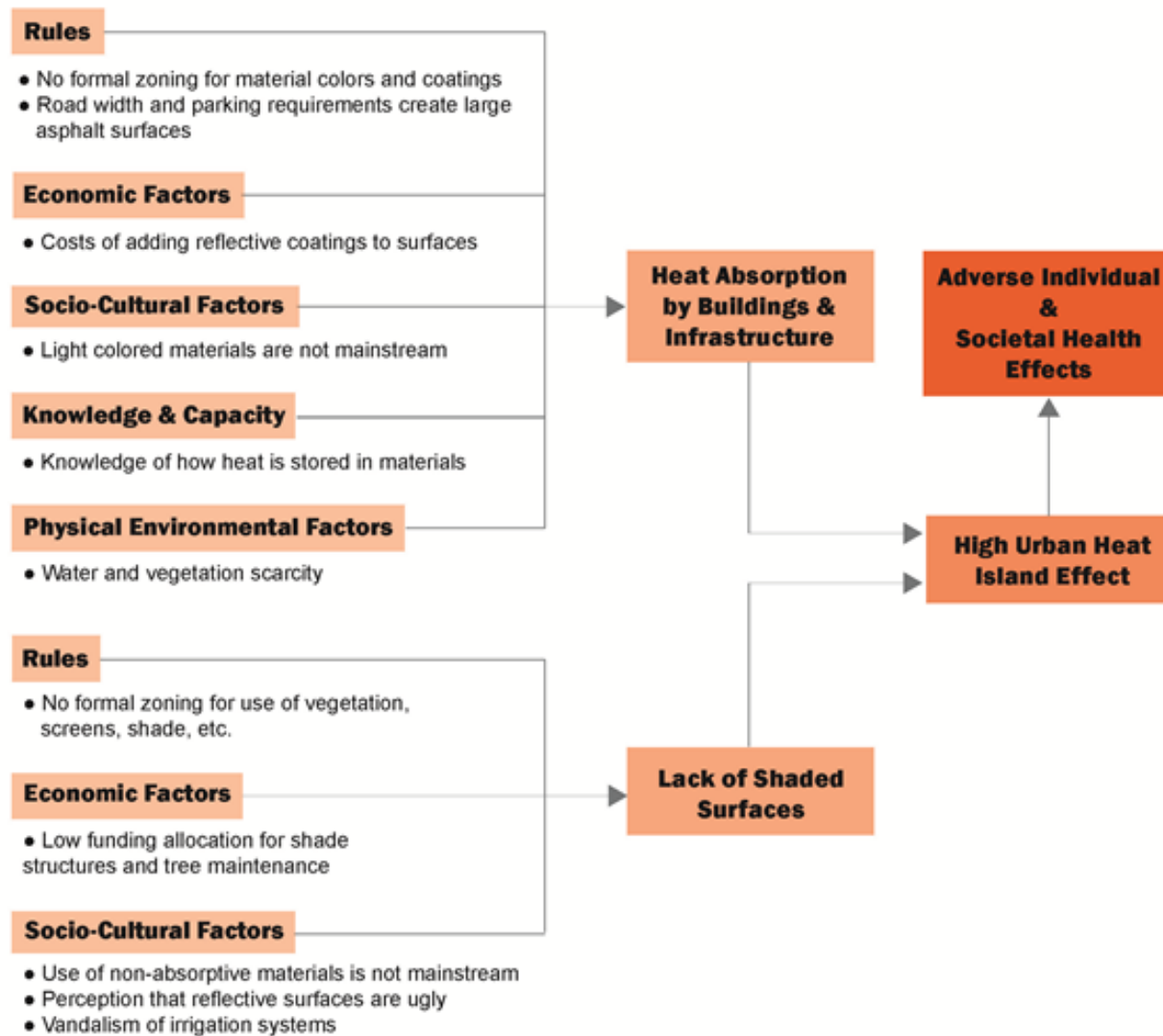


Figure 18. Reduce daytime temperature problem map

Heat absorption by buildings and infrastructure, and a lack of shade, drive the UHI effect. Darker materials tend to have lower reflectance, absorb more solar radiation, and thus increase outdoor air temperatures. Tall buildings with narrow spacing can trap solar radiation and heat (Giguere, 2009), especially near the ground. UHI in Phoenix is compounded by a dearth of shade and low funding for shade structures and tree maintenance. Although there is zoning for initial vegetation, screens, and shade, there is little subsequent regulatory protection of plants and trees. This leads to property owners often removing vegetation in favor of further development.

Others drivers of high daytime temperatures include negative perceptions of reflective and non-absorptive materials and insufficient capacity and funding to retrofit existing infrastructure. Current design and construction practices do not utilize heat-reduction techniques, and many people do not understand the economic, environmental, aesthetic, and social benefits of vegetated landscapes and trees. Finally, heat absorption and high surface temperatures lead to heated stormwater runoff and more heat-related illness.

Focus areas for temperature reduction are zoning for heat reduction efforts (e.g. reflective material colors and coatings), support for property owner UHI mitigation, and marketing for colors and materials that reduce heat.



## 5.4. Goal 4 – Problem map of increasing green systems benefits to health, mobility, and the economy

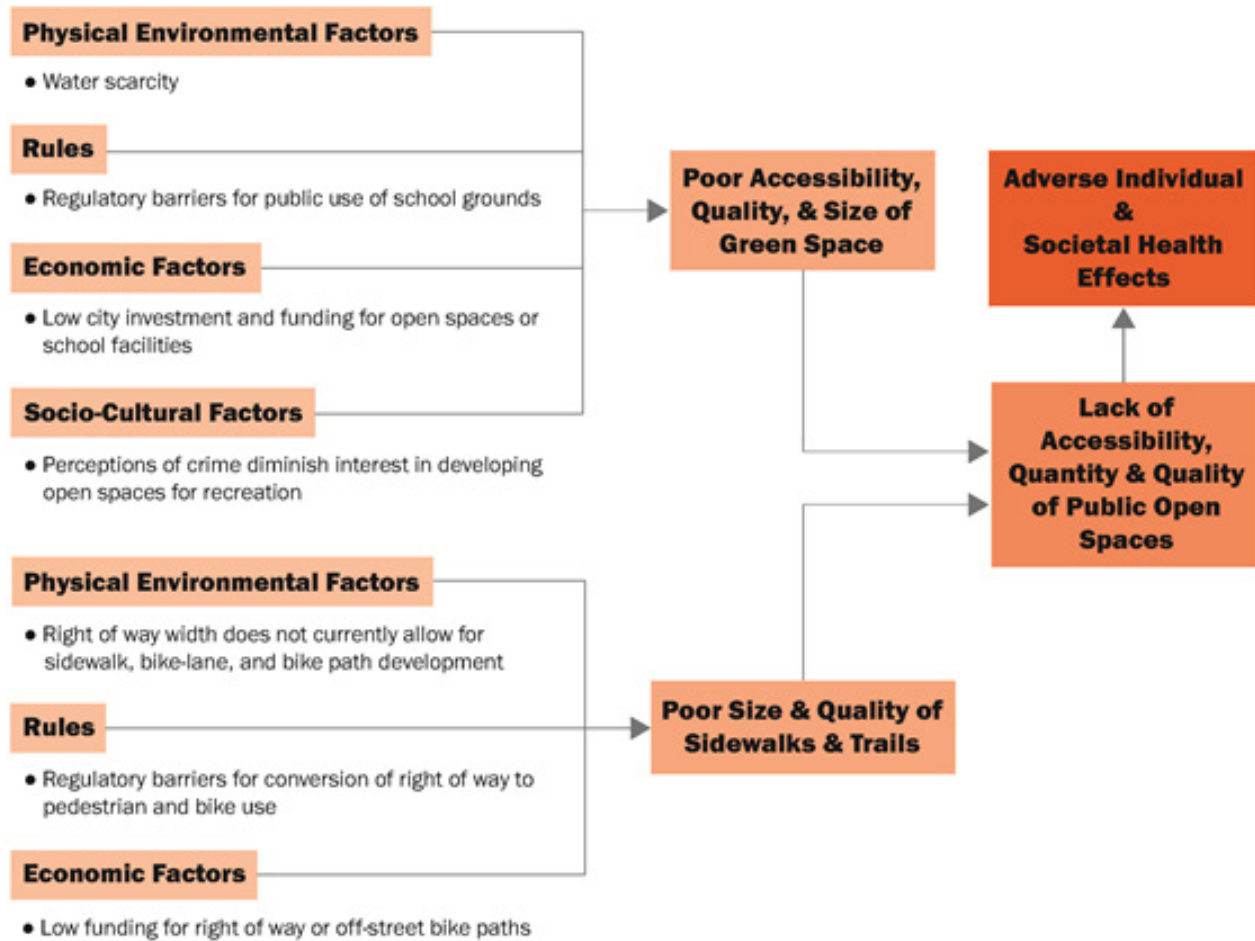


Figure 19. Accessibility, quality, and size of green space, sidewalks, and trails problem map

Figure 19 illustrates the upstream drivers that affect the accessibility, quality, and size of green space, sidewalks, and trails. Water scarcity and low city funding for open spaces are exacerbated by perceptions of crime in open spaces, often driven by poor lighting and site selection. Regulatory barriers to public use of school grounds for recreational purposes limits access to what might otherwise be open space. City acquisition of new land for green spaces can be challenging and expensive, and high temperatures from the UHI effect disincentive investment in outdoor recreation areas.

Poor and size quality of sidewalks and trails stems from inadequate right-of-way (RoW) widths for bike and pedestrian paths, and low funding for RoW bike lanes. Streets designed for automobiles, instead of bikes and pedestrians, leave bicyclists and pedestrians feeling unsafe, and discourages use of existing paths. Code complicates these problems by limiting the height and density of vegetation, and thereby its ability to shade and cool bike and pedestrian paths. Mitigation strategies include funding improvement and new uses of current open spaces, and removing RoW policy barriers.

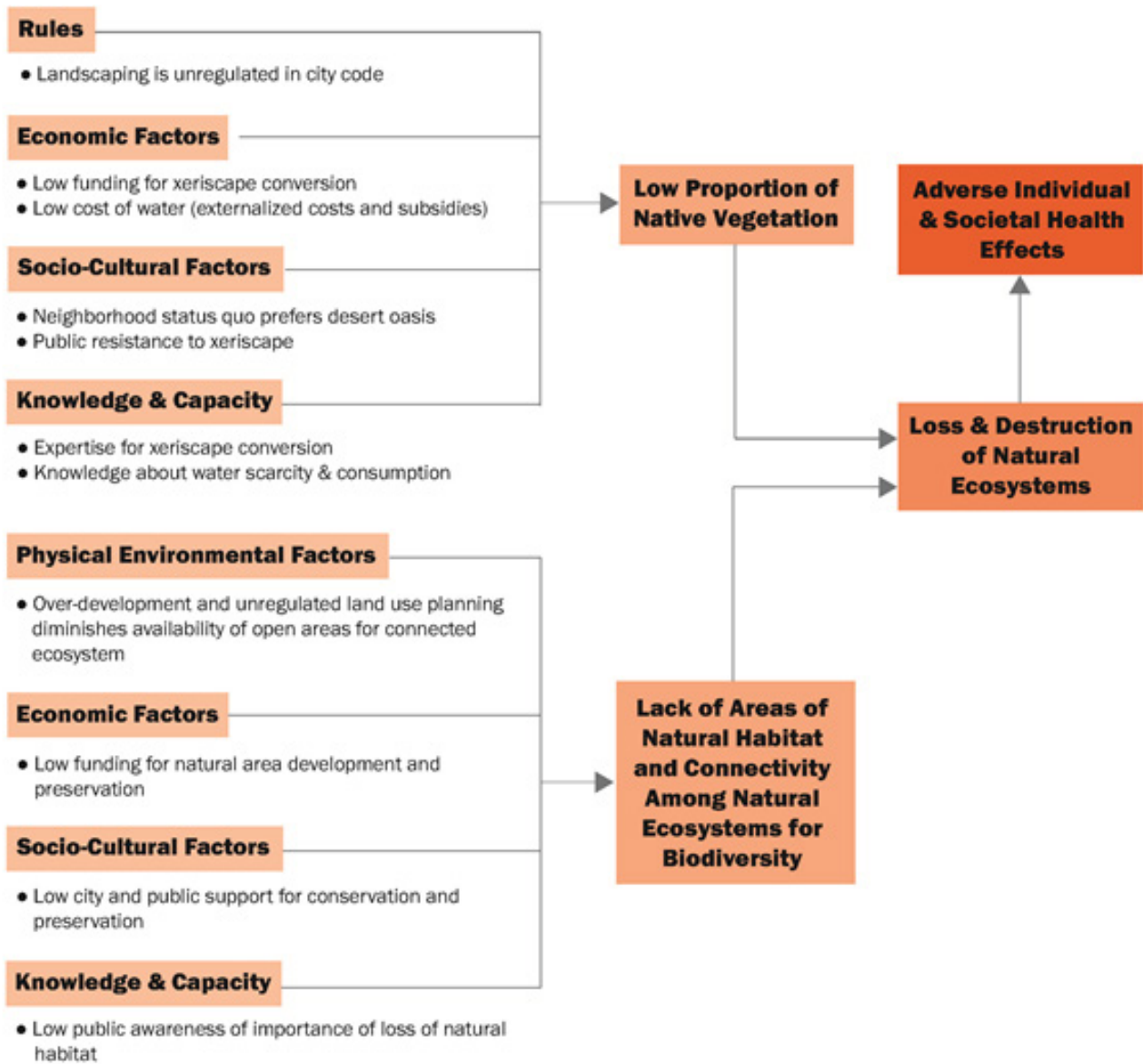


Figure 20. Limited native vegetation, ecosystem connectivity, and biodiversity problem map

Figure 20 shows the drivers of native biodiversity and ecosystem degradation. Cultural preferences for oasis vegetation, the low price of water, and landscaper unfamiliarity with xeriscaping all support conversion of native vegetation to non-native. Similarly, cultural preference for suburban development over natural open space, low funding for such open space, and low public knowledge of benefits from biodiversity and ecosystem services support the loss of ecosystem biodiversity and connectivity.

# Chapter 6 – Conclusions

## 6.1. Priority areas

The current state of green systems in the Solano District is extremely unsustainable across the goals of sustainable green systems, particularly in lowering temperatures, managing stormwater, and providing vegetation. As climate change continues to impact the Southwest with rising temperatures, longer droughts, and less precipitation, water resources will be ever-increasingly stressed and aquifers will reach dangerously low levels. If stormwater management and water consumption issues are not addressed, the District might face rising water costs and tensions among citizens about water access.

In reviewing our sustainability assessments, stakeholder input (Wiek et al., 2012), and HUD's livability principles, there are priority areas for the Solano District to address in the process of achieving low temperatures, more shade trees, and naturally managed stormwater.

1. High temperatures in Solano command attention for mitigation. Surface and air temperatures have significant effects on human thermal comfort, and District temperature data reveal that only 7.8% of land in Solano meets the sustainable threshold for thermal comfort in Phoenix. With global warming driving higher temperatures, and increased urban development as the city's population continues to grow, it will be essential for the District to address climbing temperatures. If these UHI issues are not addressed, Solano could see increases in heat-related illnesses and diseases from declining air quality. In addition, the District will face rising costs to cool buildings as temperatures continue to increase.
2. Water management is another major green systems challenge. Potable water use is very high for indoor residential use, and little stormwater is managed naturally. With climate change increasing uncertainty about the Valley's water future, water conservation is a serious issue. Sustainable water management could also improve the District's dearth of trees and subsequently help reduce temperatures.

The priority for all goals is to overcome institutional and social barriers to sustainable technologies and practices. Further analysis of all four goals will be critical for developing effective strategies. Without intervention, Solano will waste water and stay hot.

## 6.2. Promising intervention points

[Strategy previews will go here, once they are developed.]

## 6.3. Trade-off issues

There are issues this assessment failed to address, namely that tradeoffs between elements might complicate the full achievement of all ideas. Ideally, we would understand each of these tradeoffs, and define a conflict-free space. For example, there are conflicts between water use, landscape quality, and the cooling of homes. Water use is an environmental sustainability issue, but temperatures drive a host of health and energy problems. Lower water use is good for water conservation, whereas higher water use improves the local landscape and thermal comfort. There is a similar conflict between air conditioning, which can improve health, and energy use. Such tradeoffs will be further addressed in our strategy reports.

## 6.4. Improving assessment

More research is needed to provide evidence-based targets for indicators that operationalize the goals of sustainable green systems. In concert, sufficient data to assess performance relative to those targets is also lacking in some areas. It is our hope that this rigorously arranged assessment, even with missing data or thresholds, will lead to research that fills data gaps and provides for better assessments. Public agencies could support these efforts by collecting relevant data, making it accessible, and facilitating a better understanding of sustainability issues in green systems. With evidence-based targets and sufficient data for sustainability assessments, interpretation of distances-to-target would be better linked to priorities expressed by researchers, stakeholders, and funding bodies.

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# Appendix

Introduction to the Solano District

Ecological History

Canals

Ranching

Past Commercial Uses

Parks

Industrial Uses and Parking

Mapping Analysis

Data

Land Use

Zoning

Building Footprints

Shade

Water Use

Surface Temperatures

Surface Porosity

Detailed Site Exploration

Site 1. Apartments (40th Street, North of Van Buren. Near Chinese Cultural Center)

Site 2. Office Parks (44th Street and Van Buren)

Site 3. Single Family Homes (27th Street and Portland)

Site 4. Schools (Location: 30th Street and Fillmore)

Site 5. Industrial (Location: 26th Street and Washington)